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An analysis of three elementary science programs in the design of a competency-based pre-service elementary science education program.

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AN ANALYSIS OF THREE ELEMENTARY SCIENCE PROGRAMS IN THE DESIGN OF A COMPETENCY-BASED PRE-SERVICE ELEMENTARY SCIENCE EDUCATION PROGRAM

A Dissertation Presented

By

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DEDICATION

TO

GAIL: who loved,

YIN YANG: who comforted,

BARRY: who needed.

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(June 1972)

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ABSTRACT

The primary purpose of the dissertation was an analysis of three elementary science programs to ascertain the competencies necessary to teach these programs and to design a competency-based pre-service program in elementary science that reflect the necessary competencies. The focus of the design followed the American Association for the Advancement of Science guidelines of 1970 for the pre-service preparation in science for elementary school teachers. The five guidelines selected were:

I. Scientific Inquiry

II. Attitudes Toward Science

III. Processes of Science

IV. Scientific Knowledge

V. Continuous Learning

The content format for the competency-based program was a course in Natural History presently recommended for elementary education majors at the University of Massachusetts School of Education.

The thesis is divided into five chapters. Chapter I is directed toward the purpose and significance of the study. It is indicated that

the philosophical and psychological assumptions of the modern elementary science programs are most often antithetical to the practices involved in the pre-service science training of elementary teachers.

Chapter II presents a review of the relevant literature. The review is concerned with the five AAAS guidelines as parameters for teacher education. Each guideline is examined in terms of empirical and speculative positions for the preparation of teachers.

Chapter III is a philosophical and psychological rationale for competency-based teacher education programs. It is indicated that knowledge-based programs have no predictive value for future performance in the classroom. Competency-based programs, it is noted, provide a bridge between knowing and doing. Various psychological positions are presented to support the need for competency-based programs. Included in this chapter is an examination of the application of systems analysis for the design of teacher education programs.

Chapter IV is a description of the methodology involved in the study. The three programs used for analysis are the Science Curriculum Improvement Study, the Elementary Science Study, and Science--A Process Approach. A summary description of the three programs is provided.

The competencies selected from the three programs were arranged into learning hierarchies within the AAAS guidelines. These were in turn reviewed by a panel of experts for reactions. Modifications were made as a result of the panel's responses.

The competencies were arranged into ten instructional modules. A sample of pre-service teachers participated in the modules and evaluated them. The modules were also evaluated by a sample of in-service teachers using one of the three programs.

Chapter V indicates the implications for further study. It is noted that the worth of any teacher education program can only be determined by an evaluation of it's effects it had on the pupils the teachers would teach. Competency-based teacher education has to become product-based teacher education. It is urged that process-product research be performed on the competencies to ascertain the affectiveness of the program.

INTRODUCTION

The education of the American elementary school teacher is presently under attack from within and without the profession. For the past twenty years, every major professional organization concerned with education has issued a statement on the need for reform in the area of teacher education. There has been a plethora of conferences, recommendations, and guidelines on the question of how to best educate future teachers. Social critics outside of the profession have been quick to indicate that many of the problems of contemporary society as a whole could be traced to the teaching process. Silberman (1970) notes:

> . . .there is probably no aspect of contemporary education on which there is greater unanimity of opinion than that teacher education needs a vast overhaul. Virtually everyone is dissatisfied with the current state of teacher education. . .[p. 413]

A traditional pre-service teacher education program for elementary teachers consists of a series of courses in the professional area and a core program in the liberal arts. Little attention is directed toward the competencies one should possess to be an effective teacher. The assumption underlying the philosophy of a traditional teacher education program is that if a prospective teacher completes a specified sequence of courses, he is competent to enter an elementary classroom and teacher. The emphasis is on the completion of a certain number of prescribed courses regardless of whether or not the student acquires the necessary skills, knowledge, and attitudes in a given area. Teacher education programs of this type tend to be temporal and structured around the needs and resources of the institution; few are built on an assessment of the role of the teacher in a changing society.

In recent years, there has been a movement away from the credit-hour certification program in teacher education. Instead of attempting to certify a teacher on the basis of the number of credits a student accrues, teacher educators are focussing on a systems approach to define what competencies are necessary for a prospective teacher. By a systematic analysis of the purposes, the processes, and the components of a teacher education program, specific competencies can be developed to which the students are held accountable (Cooper and Weber, 1971). Such an approach is called Competency-Based Teacher Education. It is "a program in which the competencies to be acquired by the student and the criteria to be applied in assessing the competencies of the student are made explicit" (Weber, 1970, p. 2). The competencies specified are attitudes, skills, understandings, and behaviors that will facilitate the intellectual and emotional growth of children.

Competency-based teacher education was the primary approach in designing the nine Model programs in elementary pre-service preparation under contract by the United States Office of Education (U.S.O.E., 1968). The purposes of the programs were stated as specific competencies which were to be acquired by the prospective teacher. The competencies were arranged as a series of instructional alternatives. The components were in the form of self-directed learning modules. The Models represent total teacher education programs; not a collection of individual courses.

The preparation of elementary teachers is no easy task. They are often expected to teach language arts, social studies, mathematics, science, health, fine arts, and physical education. In the past, various commissions representing these content areas would periodically issue guidelines on the minimal number of credits and courses a prospective teacher would need to teach a given subject on the elementary level. Some of these guidelines went so far as to define the scope and sequence of the "suggested" courses.

In the area of elementary science, such recommendations were issued in 1932 and 1947 by the National Society for the Study of Education (NSSE, 1932, 1947). The American Association for the Advancement of Science (AAAS) in conjunction with the National Association of State Directors af Teacher Education and Certification (NASDTEC) made specific course recommendations in the area of elementary science education as recently as 1963 (AAAS/NASDTEC, 1963).

The AAAS/NASDTEC guidelines appeared before the development of many of the new elementary science curricula supported by the National Science Foundation (NSF). As a result of the emergence of these elementary science programs and the Models in elementary teacher education, th AAAS Commission on Education called for a series of conferences to examine the pre-service science education of elementary teachers. The conference resulted in a report that focussed on the standards, guidelines, and recommendations for "assisting prospective elementary teachers to acquire the competencies necessary to reach the new science programs" (AAAS, 1970, p. 5). This represented a bold step in the formulation of guidelines in a specific curriculum area. For the first time, a report was directed toward necessary competencies; not courses and credits. It was also unique in that an effort was made to concern itself with a total teacher education program and not science alone.

The participants in the conference directed their energies toward the problem of reconciling the philosophical and psychological rationale at the college level. Each of the new programs is unique in its own way, but all possess certain commonalities. All of the curricula emphasize the process and inquiry nature of science; not a collection of unrelated facts. There is active involvement of the child in the investigative process and the conviction that children have the ability to seek out answers to particular problems. All have a sequence of instruction that presents a unified view of science rather than an approach that is fragmented and compartmentalized.

The AAAS Commission participants viewed the traditional undergraduate science preparation for the prospective elementary teacher as being fact oriented, providing little opportunity for self-discovery, and not reflecting in content the science topics taught in the elementary school.

A recent study of science education for elementary school teachers found that teachers viewed their undergraduate preparation as being "irrelevant," "uninspiring," and often "overwhelming" (Bruce and Eiss, 1968, p. 2). Such responses result from college teacher preparation programs that focus on unrelated details and do not reflect the current trends in elementary school science.

Commenting on the outlook of elementary science education for 1980, Willard Jacobson (1967) states:

> It is becoming apparent the new programs depend very greatly upon imagination and resourcefulness of the classroom teacher. . . . In order to do this effectively, the teacher needs foundational understanding of the new programs. In order to develop those understandings, specifically designed teacher education programs will have to be prepared in conjunction with the new programs. [p. 7]

It is evident we need teacher education programs in elementary science that reflect the "new" science and are directed toward the competencies necessary to teach these curricula. It is also imperative to have a vehicle of instruction which can be used to operationalize a competency-based teacher education program that will provide a unified view of science.

CHAPTER I

THE PROBLEM

Purpose

In June of 1961, the American Association for the Advancement of Science (AAAS, 1961) issued a position statement on the instruction of science for the elementary student. The recommendation of this report was that instruction in science should be a regular part of the school curriculum from kindergarten through grade nine. As a result of this recommendation, there soon developed a series of curriculum projects supported by the National Science Foundation (NSF) that were directly concerned with science on the elementary level. The current growth and development of the projects indicates that within the next few years, a substantial number of elementary schools will be using one of these programs (Lockard, 1968, 1969, 1970).

The rapid proliferation of elementary science curricula during the past ten years presents an unusual paradox in the pre-service science education of the prospective teacher. The philosophical and psychological foundations of the new curricula are for the most part antithetic to the methods of teacher training in elementary science. Each of the programs in elementary science is unique, but all possess certain commonalities. There is a focus on the discovery aspect of science and the child's ability to independently seek out answers to particular problems. Children are encouraged to become involved in the investigative process with an emphasis on individualization. All of the curricula have a sequence of instruction that presents a unified view of science rather than an approach that is fragmented. Undergraduate science courses are for the most part inappropriate to meet these ends. Hurd (1970) indicates that "little is said in these courses about what science is, why there is a search for order and understanding or how science fits into the 'real world'." [p. 650]

It is unreasonable and unnecessary to expect elementary teachers to learn all the science needed to teach the new science curricula. It is unreasonable because were the content of these curricula translated into college level science courses, it would amount to an enormous number of semester hours and unnecessary because the new programs do not emphasize the acquisition of content but the processes involved in a scientific investigation.

The very nature and structure of science is alien to a teacher education program that focuses on specific facts and cookbook approaches to experimentation. Stronk (1971) notes that "the critical spirit that is the life of modern science demands that we accept the conclusions of scientists only after we are familiar with the methods used to support these conclusions" [p. 331]. The scientific revolution is counter to authoritarianism; yet teachers continue to ask students to memorize. Science is not only a detailed organization of minute facts and complicated theories. These are the results or products of science. Science is both process and product. Commenting on the structure of science and the teaching-learning process, Schwab (1961) notes:

> How we teach will determine what our students learn. If a structure of teaching is alien to the structure of what we propose to teach, the outcome will inevitably be a corruption of that content. [p. 9]

Potential elementary teachers enter college with a wide spectrum of skills, attitudes, and knowledge in science. Little has been known to be done in attempting to individualize the pre-service science education of elementary teachers. Regardless of individual differences, science education for the prospective teacher is essentially a lock-step program which requires each student to follow the same series in a uniform length of time.

The problem becomes one of conceptualizing a pre-service program of science education that would allow the maximum development of the abilities of each prospective teacher. A program of this nature would acquaint the teacher with the advantages and techniques of such an individual approach for use in their classroom. Throughout the design of such a program, there should be an emphasis on good science and good education.

Rather than attempting to define what a prospective elementary teacher will need in terms of specific science content areas, it would be advantageous to establish the competencies necessary to carry on an effective program in science in the elementary classroom. Dunfee (1967) sites numerous investigations which indicate that the "mere acquisition of college credits in science will not guarantee improvement in science instruction in the elementary school." [p. 56]

A survey by the Commission on Science Education of the AAAS (1968) was conducted to ascertain from the directors of the new elementary science programs their conception of the "ideal elementary science teacher." The following are excerpts from the survey:

Glenn Berkheimer of the Science Curriculum Improvement Study:

> . . . the teacher's attitude and the way she interacts with children during the science lesson are much more important than subject matter background. College educators have been assuming that teachers with the greatest number of credit hour in science content are the best teachers. I challenge that assumption. [p. 19]

Randolph Brown of the Elementary Science Study:

> Her college science AND science education courses should have sufficient coordination so that cognition discrepencies are not established. [p. 19]

Arthur Livermore of the AAAS:

> It is not necessary for the teacher to have an extensive knowledge of the facts of science, but he should be familiar with the techniques of investigation in several fields of science. . . [p. 20]

Okey (1971) has found that prospective elementary teachers do not acquire the necessary competencies to teach elementary science from their college science courses. Hurd (1970) has similar sentiments about the effect of introductory college level science courses. Courses of this type are usually for non-majors and are intended to expose the student to the important concepts of a particular science and the outstanding contributions of the field to the general fund of knowledge. It cannot be expected that teachers trained in this manner will engage their students in a program of science that focusses on individuality and the spirit of inquiry.

The AAAS (1970a) final report on the pre-service science education for prospective elementary teachers indicates five guidelines on the role of the science experience:

> I. Science for elementary teachers should be taught in the same style of open inquiry that is encouraged in elementary science programs. The students' science experiences should develop his ability to actively investigate natural phenomena and should result in his enthusiasm for and confidence in teaching science through inquiry to children. [p. 14]

II. Science experiences of elementary teachers should develop in teachers an appreciation for the historical, philosophical, and current significance of science to society, and positive attitudes about science which result in a more objective approach to everyday problems, in improved teaching of science in their classroom as well as in increased interest in science-related activities. [p. 14]

III. The science experiences for elementary teachers should develop competence in inquiry skills or processes of scientific inquiry. [p. 16]

IV. The content of college science experiences for elementary teachers should be selected so that the topics studied by teachers provide, as a minimum, an adequate background for the topics taught in elementary schools. [p. 18]

V. Science experiences should be selected so as to develop a capacity and disposition for continuous learning which the teacher should demonstrate by engaging in science activities which will provide new information and experiences capable of affecting existing attitudes, ideas, and teaching. [p. 20]

These guidelines can be summarized and grouped in five competency categories:

I. Scientific Inquiry

II. Attitudes Toward Science

III. The Processes of Science

IV. Scientific Knowledge

V. Continuous Learning

Today, more than ever, we need teachers that possess the necessary competencies to teach the new programs in elementary science. It is obvious that the traditional teacher education program in science education is not providing for the acquisition of these competencies. To this end, it will be the purpose of this dissertation to:

1. Analyze three major curricula in elementary science and ascertain the competencies necessary to teach these programs.

2. Develop a competency-based teacher education program reflecting the five guidelines of American Association for the Advancement of Science.

3. Organize the program within the context of a course in Natural History, presently recommended by University of Massachusetts to education majors.

Significance

The significance of the following dissertation can be viewed in terms of three needs:

1. A need to develop a competency-based teacher education program that reflects the current trends in elementary science.

2. A need to provide teachers with an interdisciplinary and unified perspective on the natural world.

3. A need to incorporate the resultant competency-based program into the Model Elementary Teacher Education Program (METEP).

To develop a competency-based teacher education program that reflects the current trends in elementary science.

The substance of the expression "we teach as we are taught" is not without foundation. A teacher who fails to acquire the spirit of science is not likely to convey this quality to his own students. The AAAS (1970a) summarizes this assumption by stating:

> If elementary teachers are to present science as an exciting exploration of the natural world where pupils have ample opportunity to interact with that world, to ask questions of nature as well as of people, and to discover that even young people can find order there, teachers, too, must have such an opportunity. [p. 12]

Numerous studies (Dunfee, 1967; Bruce & Eiss, 1968; Blosser & Howe, 1969) indicate that elementary teachers:

1. lack general knowledge in science
2. fear of science
3. exhibit negative attitudes toward science
4. view science as specific facts

Teacher education programs should be concerned with bringing about a reversal of these findings.

The college methods teacher that lectures on the inquiry nature of science is doing little to promote a learning how to learn philosophy and is not contributing towards the facilitation of a self-directed learner. Educators are quick to admonish their students for not taking an independent approach to learning and yet these same professors will utilize standardized testing procedures to evaluate their students.

The "we teach as we are taught" adage has been substantiated by ample research evidence. Flanders (1969) summarized the current findings in teacher-student interaction by stating that teachers "talk between sixty-five and seventy-five percent of the time. . ." (1429). Gallagher (1965) observed that most pupils respond in terms of pure memory to a teacher's question. In a unique study by Rowe (1968), it was found that a significant number of teachers wait a mere 0.9 of a second for a child to answer a question before calling on another child or asking another question.

The acquisition of additional credits in science will not cure the above stated ills. The teaching of science on the elementary level could be improved if science educators were to concentrate upon developing a set of competencies which elementary teachers should possess relative to the teaching of science rather than assuming that the completion of a specified number of courses will produce an effective teacher. Sharefkin (1962) investigated the relationship between the pre-service science training of student teachers and the possession of six specific science competencies. The competencies examined were:

1. identifying and defining problems
2. suggesting or screening hypothesis
3. selecting validating procedures and designing of experiments
4. evaluating critically claims and statements of others
5. reasoning quantitatively and symbolically

Sharefkin (1962) suggested that criteria are needed to help student teachers clarify their own conceptions of, as well as an identification of, children's behaviors which exhibit the science abilities emphasized in the study. She concluded that elementary school student teachers need to develop an awareness of their limitations in the six competency areas.

Butts (1965) investigated the relationship of problem-solving ability and science knowledge. He found that problem-solving behaviors were not significantly correlated to a person's knowledge of facts and principles of science.

In the area concerned with the development of competence in question asking, Moyer (1965) found more than fifty percent of teacher questions were introduced with HOW, WHAT, WHY, WHO, WHERE, WHICH, and WHEN. He did not find evidence of questions that required students to evaluate. Moyer inferred that teachers are not prepared to ask questions in a way that will stimulate their students to think about scientific concepts. Upon interviewing a number of the teachers involved in the study, Moyer found they received almost no instruction relative to the development of questions as a pedagogical technique.

The majority of the modern "methods" books on teaching science in the elementary school emphasize procedures as inquiry training, discovery learning, problem-solving, self-directed learning, and the individualization of instruction. Ramsay and Howe (1969) in an analysis of research related to instructional procedures in elementary science found the lecture-demonstration method the primary means of instruction. Individualized instruction, critical thinking, inquiry training, problem-solving, creativity, and concept development are only being given lip-service. Teacher training should become "a procedure for closing the gap between the behaviors which do occur and the behaviors which educators believe should occur by training the teachers in the desired behaviors" (Rosenshine & Furst, 1971, p. 39).

> To provide teachers with an interdisciplinary and unified perspective on the natural world.

The division of science into various components is a tool to assist the scholar. The existance of the separate categories of biology, chemistry, and physics represent man's inability to visualize phenomena as an entity. One of the unique contributions of science has been the unification of knowledge. There is a knowledge explosion, but the accumulation of knowledge points to unifying principles; not fragmentation.

Albert Szent-Gyorgi (1970) aptly states, "If I go into nature, I do not see physics or chemistry anywhere. What I see is light or darkness, rocks or clouds" (p. 3). Science has been described as a special way of looking at ordinary things. It may be viewed as a continual search for first principles. Shamos (1969) commenting on the conceptual schemes approach to science notes, ". . .unifying theories are the main goal of science and should be the focal point of a science curriculum" (p. 301). The entire trend of modern science is to find a common basis for all our experiences.

Natural History represents a unique curriculum vehicle to operationalize a competency-based program for perspective teachers. It is a discipline that focusses on the cause and effect relationships that exist in the natural world. Nutting (1968) in the introduction to his laboratory guide indicates that:

> Under the press of modern hot house living with our being dependent upon the recent advances in molecular biology, our attention focussed upon space travel and an insufferable but hopeful barrage of scientific detail we tend to become disoriented in terms of our natural environment. [p. 1]

The division of knowledge into smaller and smaller categories is bringing about an "ecological crisis" in science. The study of astronomy should not only direct itself to the planets, constellations, and space travel. The prospective teacher should examine the question of the earth's and moon's relative position to the sun and the effect this would have on meteorological phenomena. The resultant climatic changes should than be examined as the causative factors in geological and biological processes.

Prospective elementary teachers should bring to the classroom a unified view of the natural world. By presenting science as biology, chemistry, and physics, we are distorting the nature of the discipline.

An introductory course in a biological or physical science will not contribute to a perspective teachers view of what science is all about. Shamos (1969) notes that "to be effective, science education must be extensive and imaginative." ". . . it is not simply a matter of skills or of absorbing a lot of facts, but of a different way of looking at things, a different way of reasoning, . . .in short, the kind of activity that is foreign to normal experience" [p. 300].

> To incorporate the resultant competency-based program into the Model Elementary Teacher Education Program.

In October of 1968, the School of Education of the University of Massachusetts was awarded a contract to develop a model program in elementary teacher education. The resultant Model Elementary Teacher Education Program (METEP) was explicit in requiring "the specification of instructional and program goals in terms of behaviors to be exhibited by the trainee" (Allen & Cooper, 1968). The science component of the METEP identified three broad competency areas:

1. knowledge and thinking
2. values
3. skills

In 1969, a feasibility study was conducted on the METEP (Cooper & Ojala, 1970). The introduction to the science area written by Konicek stated:

> Science is both product and process. Teachers in most schools are more concerned with the former than the latter and teach to these ends. . . . If we are concerned with process as well as product, it should be possible to involve the students in process to the extent that they will be aware of more than facts which are often erroneously thought of as synonymous with science. There should be things that they can do with scientific knowledge. Is it enough to

> say that a student has amassed sixteen credits in biological or physical sciences and therefore can be certified to teach? Or can we attempt to identify some behaviors which should be performed by a teacher? [p. 157]

With this philosophical goal in mind, the science task force of the METEP proceeded to search the literature and analyze the modern curriculum projects in elementary science to arrive at the necessary behaviors for a perspective teacher to possess. The initial list was composed of some two hundred performance criteria. Due to a time limitation, the initial list was reduced to forty-four objectives. The following is a list of these objectives quoted directly from the feasibility study (Cooper & Ojala, 1970):

1. Using the library to find appropriate reference materials.
2. Changing text activities to open-ended activities.
3. Writing open-ended activities.
4. Writing open-ended questions.
5. Designing discrepent events for motivation to inquiry.
6. Categorize divergent and convergent questions.
7. Compare curricular programs.
8. Participate in group discussions on student involvement.
9. Take an exemplary test.
10. Play with materials of inquiry type curriculum.
11. Read children's science periodical.
12. Read teachers science periodical.
13. Witness exemplary lesson using media.
14. Plant seeds and keep a log.
15. Participate in lab equipment building lesson.
16. Estimate size of specimen in microscope field.

17. Calibrate microscope field of vision.

18. Use microscope.

19. Strip wire.

20. Bend glass tubing.

21. Mix acid and water properly.

22. Break glass tubing.

23. Fire polish glass tube.

24. Smell gas.

25. Fold and use filter paper.

26. Solder two wires.

27. Classify objects three ways.

28. Make dicotomous key.

29. Use dicotomous key.

30. Make galvanometer.

31. - 34 measure voltage drop.

35. Measure current flow.

36. Pass battery and bulb paper test.

37. Order rocks according to hardness.

38. Calculate density of liquid.

39. Calculate volume of irregular object.

41. Weigh object to one percent accuracy.

42. Measure given amount of liquid.

43. Measure out thirty grams of water.

44. Calculate density of irregular shaped solid.

(All of the above performance criteria are quoted directly from the final report; Cooper & Ojala, 1970, pp. 158-159)

Of the forty-four performance criteria, a very small proportion reflected the stated philosophical goals. Performance criteria 16-44 are all skill areas. None of the forty-four objectives focus on the process or inquiry nature of science. Students indicated that they saw no continuity or rationale for the performance criteria. Numbers 1-15 do represent important competencies for a perspective teacher to possess, however, they were presented as isolated activities. At no time did the candidates see any unifying theme or conceptual idea. It must, however, be noted that the Phase II study of METEP was primarily a feasibility study and no attempt was made to produce a formal and complete program.

The program being developed in this dissertation will attempt to rectify some of the stated criticism. The writer was involved in the original feasibility study and has a basic commitment to the philosophical goal stated by Konicek. It is anticipated that the resultant program developed in this study could be adapted to the present METEP program.

CHAPTER II

REVIEW OF RELEVANT LITERATURE

The following review of the relevant literature will focus on the five AAAS guidelines under which the derived competencies will be subsumed. Chapter III of the dissertation will provide a comprehensive examination of the philosophical and psychological rationale of competency-based teacher education.

The intent of this review is to provide a broad range of opinions and prospectives on the competency guidelines. The literature cited will be empirical and conceptual in nature. Empirically based research will be limited to those studies that support or refute one of the guidelines as a parameter for teacher education in the area of elementary science. Conceptual arguments will be directed toward philosophical positions on a specific guideline.

Scientific Inquiry

<u>Guideline I</u>:

> Science for elementary teachers should be taught in the same style of open inquiry that is encouraged in elementary science programs. The student's science experiences should develop his ability to actively investigate natural phenomena and should result in his enthusiasm for and confidence in teaching science through inquiry to children.

A review of the literature on the nature of scientific inquiry reveals that there is little agreement on exactly what is meant by scientific inquiry. Terms such as inquiry, process approach, problem-solving, and discovery learning seem to be used by a number of investigators interchangeably. There is little evidence that would indicate an agreed upon operational definition of inquiry.

Anderson, DeVito, Dyrli, Kellogg, Kochendorfer, and Weigand (1970) attempt to make distinctions between problem-solving, process approach, inquiry, and discovery. They view problem-solving as a "technique that promotes learning through confronting students with a distinct problem that demands a solution" [p. 47].

The skills necessary to carry on a problem-solving investigation, they indicate, are the processes of science. These processes are observation, classifying, measuring, communicating, quantifying, time/space relations, inferring, and predicting. The process approach to science education represents the acquisition of a distinct set of skills. It is these skills that are necessary to carry on a scientific investigation.

Inquiry, according to Anderson, et al., represents a "strategy for asking questions. . ." "Inquiry training permits the individual to observe an event, to recognize a problem or problems, to analyze the variables, to recognize relevant and irrelevant questions, to search out data, and to take complete responsibility for the entire process of obtaining, organizing, and interpreting data" [p. 58].

Discovery they conceptualize as a pedagogical procedure that is opposite to rote memorization. It is the "active involvement through direct manipulation of the hardware of science" [p. 58].

Kuslan and Stone (1968) define inquiry as "the teaching by which teachers and students study scientific phenomena with the approach and spirit of the scientist" [p. 138]. This definition is similar to Bruner's (1961) concept of the heuristics of discovery. By heuristics, Bruner means behaving like a scientist. "The Schoolboy learning physics is like a physicist and it is easier for him to learn physics behaving like a physicist than doing something else."

Gagne (1971) believes inquiry to be a terminal capacity rather than an ongoing activity. He views inquiry as a final step in a sequence of learning. Inquiry is in this instance a form of observable behavior. It is Gagne's contention that inquiry "is the terminal thinking process we want the student to be able to engage in, after he has taken all the necessary previous steps in learning" [p. 412].

Bruner (1961) and Suchman (1964) both view inquiry as part of the process of being able to make decisions. Bruner notes that "inquiry is figuring out things for oneself" [p. 2]. Suchman extends this idea by suggesting that inquiry includes "information gathering and conceptual reorganization. . . and is the process by which the learner influences and actually programs his own learning in terms of his cognitive needs" [p. 230].

Hoagland (1971) has synthesized a definition of inquiry that includes: (1) self-direction; (2) unique attitudes; (3) unique processes; (4) unique activities; and (5) a unique arrangement of these attitudes, processes and activities. It is Hoagland's contention that "inquiry is a self-directed mode of learning in which the learner selects and organizes unique attitudes, activities, and processes for the attainment of a goal" [p. 4].

Karplus and Their (1967) have operationalized inquiry into three components: (1) exploration, (2) invention, and (3) discovery. Exploration provides the student with an opportunity to have direct experiences with materials. These explorations are done in an undirected way. It is during the exploration lessons that the teacher has the opportunity to observe the children and appraise their level of thinking. By exploring freely, children have the opportunity to observe and "discover" relationships within their own cognitive framework.

In an invention experience, scientific concepts are introduced to explain what was observed during exploration. Such lessons are termed invention because the concept being introduced was previously invented by a scientist. Invention lessons are teacher directed. The designers of the SCIS program feel that children need words or labels to assist them in concept formation. It is assumed that by having a word or term to describe a series of seemingly unrelated observations, children will have a tool to make new associations.

These new associations are brought about during discovery lessons. In the discovery experiences, the child is given the opportunity to apply the invented concept in a variety of ways. The discovery aspect is not as open-ended as is the exploratory; rather it is a guided discovery. The teacher actively assists the child in making relationships by drawing his attention to a particular phenomena or event.

A number of curriculum theorists have indicated specific conditions or requirements for inquiry. Gagne (1963) states three such conditions: (1) practice in inquiry, (2) broad, generalizable knowledge, and (3) possession of critical or incisive knowledge. By practice in inquiry, Gagne means "the student should be provided with opportunities to carry out inductive thinking; to make hypothesis and to test them in a great variety of situations. . ." [p. 414]. It is Gagne's contention that without such knowledge, the student will constantly be reinventing the wheel. The possession of critical or incisive knowledge is the ability to discriminate "between a good idea and a bad one. . ." [p. 418].

Suchman (1964, 1965) indicates three factors for inquiry to take place: (1) freedom, (2) responsiveness, and (3) focus. By freedom, he means autonomy to try out new ideas. Responsiveness refers to an environment that provides something for the learner to reach out for. "The more the teacher puts into the immediate environment of the child to enable him to interact, gather information, and test ideas, the more responsive the teacher has made the environment" (Suchman, 1965, p. 30). The focus for inquiry indicates a direction and purpose.

It is obvious from the cited literature that there is little agreement on exactly what is meant by scientific inquiry. The AAAS guidelines specifies two criteria, i.e., pre-service teachers should be taught science in a style similar to the philosophy found in elementary programs and their training should provide a framework to teach others via an inquiry approach. The writer has operationalized the guideline into two primary competencies: (1) the ability to investigate, and (2) the ability to teach science as inquiry. These competencies have been subdivided into specific performance objectives that can be found in Chapter V of the dissertation.

Attitudes Toward Science

Guideline II:

> Science experiences of elementary teachers should develop in teachers an appreciation for the historical, philosophical, and current significance of science to society, and positive attitudes about science which result in a more objective approach to everyday problems, in improved teaching of science in their classroom as well as increased interest in science-related activities.

Aiken (1969) has classified research related to attitudes toward science into three broad categories. The first are those investigations related to an individual's like or dislike of science as an academic discipline. The second type of studies are directed toward an individual's feeling toward scientists and their work. The third category of research concerns itself with the attitudes one might possess in regard to scientific knowledge and how it is being utilized within the society.

Upon commenting on the purposes and objectives of science education in school, Kessen (1964) indicates that the scientific attitude is the "willingness to wait for a conclusive answer. . ." [p. 4]. Included in the scientific attitude should be a respect for the past, and a questioning of authority.

When dealing with the question of attitudes toward science and teacher education, it is important to consider whether or not teachers' attitudes are related to teacher effectiveness. Loree (1971) indicates that there is evidence to support the hypothesis that a teacher's attitude, or belief system, is related to teacher effectiveness. Bixler (1959) conducted a study to determine if an elementary teacher's attitude toward science could be transferred to children. Using a population of 1,000 children in sixty-two schools, he found that those teachers who demonstrated a favorable attitude to science caused a significant change in the attitudes of the children. In the area of student achievement, Rosenshine (1969) reports, "that ratings given to teachers on such behaviors as 'stimulating,' 'energetic,' 'enthusiastic,' and 'animated' are related to measures of pupil achievement" [p. 15].

From such evidence, it would seem that a positive attitude toward science would be a desirable competency for a prospective elementary teacher to possess. However, investigations directed toward the attitudes of practicing teachers indicate that on the whole, elementary teachers demonstrate negative feelings toward science. Wytiaz (1962) and Victor (1961) both found a reluctance to teach science by a majority of elementary teachers. In Wytiaz's sample, 51.1% of the teachers indicated a fear of teaching science as a result of inadequate college preparation. The investigation demonstrates a deep concern with the kind of undergraduate science education the teachers received. "It was felt by the teachers that college should provide a science program that would be more practical for the student preparing to teach in the elementary grades" [p. 152].

Victor's (1961) survey presents a tragic picture of the undergraduate science program for the perspective elementary teacher. He notes that "the most common reason offered for the reluctance to teach science is the inadequate science background of the elementary teachers."

One hundred six teachers responded to Victor's questionnaire with the following results indicated:

1. 79.1% would not teach an unfamiliar subject such as science.
2. 75.8% would not handle unfamiliar equipment.
3. 73.6% often found it difficult to locate suitable experiments, science equipment, and supplemental reading.
4. 65.5% often found it difficult to answer some of the questions raised by pupils interested in science.
5. 64.0% were often disconcerted by the possible questions about a phase of science with which they were unfamiliar.
6. 60.7% were often placed in a position of having to say, "I don't know," when asked about a phase of science with which they were unfamiliar.

Soy (1967) investigated some of the attitudes of perspective elementary teachers toward science as a field of speciality. She found that only art with a four percent acceptance level had a lower rate than science with a 7.1% acceptance level. Soy makes a plea for a re-examination of the "college curricula in elementary education in order to see what can be done to develop teachers with feelings of competency in a broader range of subject areas, particularly in the field of science" [p. 516].

The evidence for negative attitudes toward science by practicing teachers is substantial. Such evidence would indicate a need to provide a pre-service elementary science program that would bring about a positive attitude or a change in the belief system toward science. The question becomes one of how can a pre-service experience facilitate a positive attitude in the area of science?

Loree (1971) indicates two basic methodologies that have been used to bring about attitudinal changes. The first of these he terms informational input. In this method, "newly acquired information is expected to change the belief system of the learner" [p. 109]. The second methodology he views as experiential. By engaging in an experience, "a change in attitude is expected to emerge out of the effort of the learner to cope with his learning task" [p. 109].

Loree (1971) cites a number of studies that demonstrate that it is possible to modify the belief systems of teachers through course work. It should be noted, however, that students may discover the values and attitudes of their instructors and significant changes on attitudinal scales may reflect acceptable beliefs, not their personal convictions.

Loree (1971) does believe that attitudinal changes can be brought about through course work, but under certain conditions. He notes:

> It is not surprising that college courses can affect changes in the beliefs of students. It has long been established that exposure to information can serve to form or to alter attitudes under certain conditions. Change is facilitated when the source of information is respected, when the initial attitude is not firmly entrenched, when the communication reflects attitudes that are consistant to the needs of the receiver, and when the communication is acceptable to important reference groups of the receiver. Possibly most, if not all of these conditions often are fairly well met in courses offered to students in a teacher education program" [p. 110].

There are, however, a number of studies that are contrary to Loree's position. Aiken (1969) in a comprehensive review of attitudinal studies in science indicates that in-service teacher education programs show no significant difference in the teachers' attitudes as a result of the program. Aiken (1969, p. 69) notes a study by Diel in which a physical science course was designed for non-science majors. The course was divided into two sections: the experimental group had non-directive class discussions and open ended laboratory experiences and the control group had prepared lectures and a fixed laboratory program. There was no significant difference in the attitudes toward science for either group.

Oshima (1966) attempted to bring about changes in attitudes toward science and a confidence in teaching science of pre-service elementary teachers. He used two types of elementary science methods courses for his investigation. One course was of the lecture-demonstration type and the second was that of individual investigation. Using validated instruments, he pre-tested and post-tested both groups for (1) attitudes toward science, (2) confidence toward teaching science, and (3) achievement levels in science. Oshima found no significant differences in the three measured areas.

The literature seems to present conflicting evidence on the methodology and the results on attitudes toward science for elementary teachers. What does seem to be clear is that pre-service teachers and in-service teachers have a negative attitude toward science and this attitude can be transferred to the classroom experience. Teacher education programs should focus on designing new methodologies and experiences in an attempt to bring about a change in the belief systems of teachers toward science.

The Processes of Science

Guideline III:

The science experiences for elementary teachers should develop competence in inquiry skills or processes of scientific inquiry.

As in the area of scientific inquiry, there is little agreement as to the exact meaning of the processes of science. In many instances, the idea of using the processes of science is more of a philosophical belief rather than an operational concept. The use of the processes of science as a means of coming to understand science represents a reaction to the traditional memorization of facts, theories, and laws.

The AAAS elementary science program, Science--A Process Approach, indicates that there are three elements to a process oriented program (1971):

1. Emphasis on process implies a corresponding de-emphasis on specific science "content."
2. Processes of science resemble what scientists do.
3. Processes include a method of processing information.

Atkin (1968a), a critic of the AAAS program, fears the pendulum is moving too far in the opposite direction. It is his contention that process cannot be developed in isolation from content. It is Atkin's belief that no two scientists work the same way and to attempt to isolate the processes of science is to only create a "caracuture of science." That is far too simplistic. He notes:

> A basic flaw in the process approach is the apparent assumption that science is a sort of commonsensical activity, and that the appropriate "skills" are the primary ingredients in doing productive work. There seems to be no explicit recognition of the powerful role of the

> conceptual frames of reference within which scientists and children operate and to which they are firmly bound. [p. 2]

Atkin points out that the AAAS program provides no process for what he terms "the starting leap of the human mind" [p. 3]. A scientist can observe for a life time, he can organize data, make hypothesis, and measure; yet the monumental scientific achievements have occurred more as a result of startling leaps of human mind then the stated processes of the AAAS.

Gagne (1965c), a psychologist associated with the AAAS program, argues that the content or concept view of teaching science is too narrow. He indicates that the true nature of science is a "dynamic, open-ended process of investigating natural phenomena. . ." [p. 9]. Teachers using a content approach tend to tell students facts and expect them to memorize them and rely on describing and demonstrating as the primary pedagogical procedures. It is Gagne's contention that the so called creative approach to elementary science "fails to establish a broad base of knowledge which can be generalized to any and all situations that the student may meet. . ." [p. 11].

Kessen (1964) in a statement of the purposes and objectives of science education, finds himself in basic agreement with Gagne. He indicates that content in science will constantly change; but the procedures will "remain remarkably the same from the time the kindergarten child wonders about color to the time the graduate physicist wonders about particle emmision" [p. 5].

Butts and Raun (1969) have conducted some empirically based studies on using the AAAS Science--A Process Approach program with in-service teachers. Using a process oriented in-service elementary science program, Butts and Raun found a change in the teacher's commitment to teaching science. In another study, Butts and Raun (1969) found that by using a process approach to elementary science, in-service teachers formulated positive attitudes about themselves and their ability to teach science.

The polemic of process versus content will not be settled in the foreseeable future. However, what is important for the perspective elementary teacher is that they have an understanding that science is both process and product. A meaningful pre-service teacher education program should provide the perspective teacher with the skills involved in the process of science. These skills should be presented in the context of appropriate content to provide the important connection that will bind process to content.

Scientific Knowledge

Guideline IV:

> The content of college science experiences for elementary teachers should be selected so that the topics studied by teachers provide, as a minimum, an adequate background for the topics taught in elementary schools.

The question of how much scientific knowledge is necessary for an elementary teacher has been a subject of concern for a number of years. Professional organizations such as the National Society for the Study of Education (NSSE), and the AAAS have attempted to establish guidelines for the preparation of teachers in the area of science. There is a conflict over the role of subject matter competency among educators.

In a comprehensive review of studies directed toward teacher effectiveness, Ryans (1960) indicates there is a positive correlation between subject matter preparation and teacher effectiveness. On the other hand, Ellena (1961) notes that subject matter competency is not a major factor in teacher competency.

What has been conclusively demonstrated is that classroom teachers generally have a lack of confidence to teach science as a result of undergraduate experiences. Blasser and Howe (1969) reviewed twenty-two studies on pre-service preparation in science for elementary teachers. Based on an analysis of these studies they indicate "that the present preparation programs are inadequate for teaching science, in an effective manner, in the elementary school" [p. 57]. Blasser and Howe summarized their findings by stating:

> It might be inferred, from an analysis of these research reports, that elementary school science teaching is handicapped by deficiencies in both course content and teaching methodology in so far as teacher's backgrounds are concerned as well as by inadequate teaching conditions in the schools. . . . Elementary school teachers, because they lack familiarity with science content and materials, express reluctance to teach science. . . [p. 57].

A comprehensive review of elementary school science was compiled by Maxine Dunfee (1967) for the Association for Supervision and Curriculum Development. She reviewed twenty-eight studies on the preparation of elementary teachers in science. Dunfee notes that most studies seem to indicate that teachers are most interested in courses that will help them present science as it should be presented in the elementary school.

A study conducted by Bruce and Eiss (1968) for the National Science Teachers Association suggests "that there are serious limitations which must be considered in establishing the role of science in the elementary schools and the collective role of the elementary teacher in presenting science if the present mode of teacher preparation is retained" [p. 3].

Bruce and Eiss summarized their findings by stating:

1. Certain content areas in science found in various curriculum projects left students insecure about basic ideas.
2. Students voiced concern on how to function in areas of science they had no factual knowledge.
3. Prospective teachers frequently saw a need for an integrated program involving both method and science content.

An investigation conducted by Uselton (1963) found that the mere acquisition of scientific knowledge was not enough to carry on a well integrated program of science in the elementary classroom. In a summary of his study, Uselton indicates that the "typical college science courses do not qualify the elementary teachers for science teaching. Formal course work in science may not be sufficient or perhaps another type of science course more specifically directed towards the needs of the elementary teacher candidates may be more fruitful" [p. 3807].

As a result of such investigations, professional organizations periodically issue recommendations as to the necessary preparation in science. In three separate yearbooks, the National Society for the Study of Education (NSSE) made specific recommendations. The thirty-first yearbook (1932) indicates twenty-eight hours of science but does not state specific areas. The forty-sixth yearbook (1947) suggests twenty hours of preparation broken down into six units of earth science, six units of physical science, six units of biological science, and two units of special methods. In the fifty-ninth yearbook (1960), the NSSE makes no definitive statement on the number of credits or kinds of courses that should be part of a pre-service teacher education program in science. The section of the yearbook concerned with the preparation of elementary teachers with competence in science states:

> With science, as with other subjects--reading, arithmetic, art and social studies--the professional task is to determine how to use the content to promote the optimal growth of the child. Ideally, the study of how children learn and how to teach them and the study of science and its relation to child growth and understanding are an integral part of the college curriculum [p. 260].

In 1963, the AAAS and the National Association of State Directors of Teacher Education and Certification (AAAS/NASDETEC) issued a statement of guidelines that removed the credit delineation, but made specific and detailed recommendations as to the scope and sequence of science content courses. These include earth and space sciences, biological science, physical science and mathematics.

The final report of the most recent guidelines for pre-service science education of elementary school teachers (AAAS, 1970) notes that earlier statements by the NSSE and the AAAS/NASDTEC placed heavy emphasis on credits and course titles. The 1970 report provides recommendations for pre-service science education that takes into account recent developments in elementary science curricula. The guidelines deal directly with the role of science experiences in maximizing the perspective teacher's competency in utilizing one of the new curricula.

A number of individual investigators have made general recommendations that they consider adequate preparation of perspective elementary teachers. Mallinson (1961) believes that good survey courses are most suitable for pre-service training of elementary teachers. Blough (1958) states that an adequate program should provide an orderly concept of the biological and physical world, an understanding of the important principles and generalizations, and an understanding of the methods and tools of inquiry. Rising (1964) contends that special courses for elementary teachers are not necessary. He is of the opinion that courses for non-majors should educate citizens, not just teachers.

No doubt, the question of how much and what kind of scientific information is necessary for the elementary teacher will be subject for debate for some time to come. It is important, however, for the teacher to sense a connectiveness between the knowledge of science and future needs in the classroom.

Continuous Learning

Guideline V:

> Science experiences should be selected so as to develop a capacity and disposition for continuous learning which the teacher should demonstrate by engaging in science activities which will provide new information and experiences capable of affecting existing attitudes, ideas, and teaching.

A review of the relevant literature reveals little, if any, research that has been done specifically in the area of continuous learning. There is no evidence available that examines whether or not elementary teachers continue to engage in science related activities or attempt to identify and correct weaknesses in their science background. The scarcity of such research would seem to indicate an open field of study. It would be interesting to investigate what experiences in a pre-service teacher education program facilitates a capacity and disposition for continuous learning.

Although there is no direct evidence in the area of continuous learning, studies conducted on in-service education have shed some light. With the growth of Federal support in elementary science education, there has been an increase in recent years in in-service education. Financial support for these programs have come directly from the Federal government and from professional organizations.

Admission to these in-service programs is primarily on a voluntary basis. Consequently, an examination of the characteristics of the applicants could provide an indication of the type of teachers that are interested in continuous learning. Gallentine and Buell (1966) contrasted the characteristics of a group of National Science Foundation in-service applicants to a summer institute to a sample of non-applicants. The applicant group averaged 14.9 credit hours of college level science while the non-applicant group averaged 10.3 semester hours. The applicant group indicated a high degree of interest in self-improvement supplemented by a regular reading program and keeping abreast of current science education from professional journals. In contrast, non-applicant teachers were found to be less motivated and more self-satisfied.

Dunfee (1967), in a review of the research related to the use of science consultants in the elementary classroom, found overwhelming support that working directly with the teacher was superior to some form of demonstration teaching. Dunfee notes a number of studies that indicate a greater degree of self-reliance and creative teaching when consultants and science specialists worked with the teacher, not with the children.

There is research needed in the area of continuous learning. If a goal of science education is to make children more independent learners and scientifically literate, the education of their teachers might have the same goal. In the area of continuous learning, it must be the function of the pre-service experience to provide such a foundation. Practicing teachers should be encouraged and be given ample opportunity to try out unique ideas in science. All of the new curricula innovations will be for nought if teachers do not continually renew their understanding of science and it's interrelationship with other fields of knowledge.

CHAPTER III

COMPETENCY-BASED TEACHER EDUCATION

Research on teacher education as related to teacher effectiveness is voluminous and for the most part, contradictory. It can be inferred from the research that no one knows what a good teacher is and equally important, no one is sure how to make one. The work of Biddle (1964), and Flanders (1969) have a single commonality; the problem of teacher education is so complex that no one knows or agrees upon what a competent teacher is. Broudy (1969) goes so far as to state that "we can define good teaching anyway we like" [p. 583].

It is becoming obvious to teacher educators and to state certification offices that the traditional means of training teachers through a system of prescribed courses and credits will not insure a competent teacher. Individuals concerned with the training of teachers have begun to seek alternative models that reflect the mass of accumulated research so as to provide the perspective teacher with the necessary competencies to function effectively in the classroom.

In recent years, there has been a movement away from the scope and sequence training of teachers towards a competency-based program of teacher education. This movement has come about as a result of new knowledge and understandings in three separate but interrelated areas. The first of these has come about due to a change in the basic philosophical constructs involved in teacher education. The publication of Teachers for the Real World under the sponsorship of The American Association of

Colleges for Teacher Education, provided a new framework for the preparation of teachers. In recent years, the Federal government has become more active in it's support towards the pre-service training of teachers. Through grants made available from the United States Office of Education, nine teacher training institutions were provided financial resources to design new teacher education models that would represent radical departures from the traditional course-credit system. State certification offices have become concerned with new approaches to certification that will insure effective teachers and provide an element of accountability to the communities they serve.

The second area that has brought about a change toward competency-based teacher education has come through the behavioral sciences. With an increased awareness of individual learning styles, teacher educators are beginning to examine the feasibility of designing programs that allow for individual differences. The behavioral objective movement has provided the impetus in attempting to specify and measure specific learning outcomes. Teacher educators following a competency-based approach to the training of perspective teachers anticipate that the basic psychological rationale used in the design of a given program could be carried over to the elementary classroom.

The third area that has had an effect on the competency-based movement has come from the field of systems analysis. The nature of systems analysis indicates a need to define the goals of a given program. Traditional programs are for the most part concerned with input variables such as time, space, personnel, and financial resources. Such programs are usually not concerned nor do they attempt to define how the perspective teacher will be different as a result of completing a given sequence. For this reason, traditional programs cannot provide feedback in the form of evaluation to bring about modification.

Philosophical Rationale

Historically, teacher education programs have centered upon knowledge as the primary criteria in the pre-service training of prospective teachers. Knowledge criteria is typically defined as a specific sequence of courses that a future teacher will complete to be considered competent to function effectively in the classroom. Such a sequence of courses will usually include a core of liberal arts, a social or historical foundations course in education, an exposure to educational psychology as applied to the teaching-learning process, and a series of methods courses.

The basic assumption underlying this approach to teacher education is that knowledge, as measured by grades and transcript records, is a basis for predicting the success of a future teacher. Schalock (1970) indicates that knowledge criteria based teacher education programs operates on the assumption that "knowledge of subject areas that relate to teaching is sufficient as a predictor of the ability to perform the tasks required of a teacher" [p. 5]. Smith (1969) correctly notes that there is no lack of theory or knowledge in the field of education. The problem of teacher education becomes one of "how to select the knowledge and train teachers to use it" [p. 47]. It is Smith's contention that "prospective teachers are now prepared in programs that provide little or no training in teaching skills. They are taught apart from the realities that the teacher will meet and are considered preparatory to student teaching" [p. 48]. Theoretical knowledge is abstract and has little applicability to the real world. If theoretical knowledge is to become meaningful and relevant to the teaching profession, it must be adapted to suit the unique reality that it meets.

During the past few years, some teacher training institutions, especially in the Master of Arts in Teaching program, have attempted to move away from the knowledge criteria based program. They have instead gone over to the other extreme, i.e., the total elimination of all theoretical knowledge and teacher training becoming an extended intern period. The assumption of such an experience-based teacher education program is that first hand experience is the best kind of training. Smith (1969) criticizes the intern approach because "the trainee learns by trial and error and a minimum of feedback. The situations that arise in his teaching are fleeting in tenure and can be discussed only in retrospect" [p. 70].

What a competency-based program provides is a synthesis of the knowledge criteria and experience-based programs. It is a bridge between the theoretical and the real world. Cooper (1967) indicates that "what beginning teachers need is more help in translating what we know about learning to actual teaching behavior" [p. 2]. For example, a prospective teacher could be sitting in an elementary science methods course listening to the professor lecture on the work of Jean Piaget and his influence on contemporary elementary science curricula. Unless this knowledge can be translated into teaching behavior that can be used in the classroom, it will remain nothing more than a theoretical consideration or worse yet, a possible test item for a final examination.

The knowledge of the Piagetian theory should be a pre-requisite to a specific behavior that can be observed and measured. The performing of specific tasks by using the Piagetian theory to provide learning opportunities in elementary science that reflect the intellectual development of children bridges the knowledge criteria with a given classroom reality. The focus of a performance based teacher education program becomes one of what a prospective teacher does, not what he knows. However, in order for the teacher to exhibit a given behavior, he should possess a theoretical knowledge.

The classroom teacher is a problem-solver. One finds great difficulty solving problems of human growth and potential on a strictly trial and error basis. In a competency-based program, the knowledge of how to solve classroom problems becomes a pre-requisite to a behavior instead of the final product.

Smith (1969) notes that:

> . . .the focus of study in a training program is the trainee's own behavior, not the content of the course. This is sharp contrast with the theoretical component where it is the situation that is to be examined and understood. In training, it is the trainee's performance that will be observed, analyzed, and modified" [p. 71].

Competency-based teacher education focusses on the integration of knowledge and performance. Specific competencies are made known to the trainee and he is put into a situation where he can perform the skill. His performance is analyzed and evaluated on pre-determined criteria. After the performance, the "trainer" will suggest possible changes. Competency-based programs represent radical departures from the knowledge based or experienced-based teacher education sequences.

Smith (1969) indicates:

An approach such as this requires a sharp break with the view that the inherent logic and integrity of courses in education should not be violated and that the student will profit mainly from systematically studying their content. This view relies heavily on transfer of learning, for it depends on the application of what is read or heard to the different real situations with which the teacher must deal. The focus of a teacher's theoretical study in a situational approach is not the content of a course, but the situations he will meet and the tasks he will perform" [p. 48].

Psychological Rationale

In the area of the behavioral sciences, there are presently two foci which have a direct influence on competency-based teacher education. The first of these is a distinct change that has come about in educational psychology in respect to how individuals learn and the second is that of the behavioral objective movement.

There is enough evidence to support the basic thesis that learning styles are a unique and individualistic phenomenon. Stephens (1967) cites numerous reviews and empirical studies that indicate no significant differences when one method of instruction is compared to another. Nochman and Opchinsky (1958) note that "different teaching procedures produce little or no difference in the amount of knowledge gained by the student" [p. 245]. Television instruction versus traditional teaching, team teaching in contrast to the self-contained classroom, large classes as opposed to small ones, and lecture techniques compared to discussion methods; the results are usually the same, no significant difference.

Teachers tend to view their classes as a single mind, not as individuals. Curricula, syllabi, and lesson plans all assume identical life experiences, the same intelligence levels, and similar perceptions of reality. Few teachers take into consideration that each individual in a learning situation brings to that situation a unique set of past experiences, and a highly individualistic conceptualization of the environment. Siegel (1967) summarizes this position by stating that "to be most effective, instruction must be tailored to the needs, capabilities, and histories of the individual learner" [p. 320].

Teaching cannot be an either/or process. When an investigator is attempting to measure the superiority of one method of instruction over another, no matter what kind of statistical compensations are made, there are only two methods being compared which theoretically could be meeting the needs of only two students. After a review of a number of contemporary viewpoints on learning, Siegel (1967) believes that the process of learning is totally idosyncratic. He concludes that "classes do not learn; students learn" [p. 320]. Psychologists have been unable to arrive at a unified theory of learning. No single theory can account for all the discrepencies that are found in a specific learning style. Siegel (1967) goes on to note that instruction can best be viewed as an "interaction between 'givens' brought to the instructional setting by the learner and the circumstances (including other persons) comprising that setting" [p. 327].

The classical idea of trying to find a unified theory of learning, is emerging as a series of generalizations. Educational phychologists generally agree to view learning as a change or modification of behavior. The question has now become how to facilitate this change best. On an initial reading of a specific approach, it would seem that there are a number of theories on how this is best accomplished, however, on closer examination, it is the language in many cases that is different and not the implicit ideas. A number of contemporary investigators (Siegel, 1967) have almost identical elements in their theories. All seem to emphasize the need for higher order processes, i.e., the need to focus on the skills of conceptualization and synthesis. There appears to be a movement toward a wholistic view of knowledge instead of attempting to arbitrarily divide reality into various domains. Another common denominator found in contemporary viewpoints on learning is the emphasis on the active nature of the process rather than the passive. A final common feature is the view that learning is idiosyncratic in nature.

Rogers (1967) writes of two kinds of learning; cognitive and experiential. He indicates that cognitive learning is the mastery of a given body of knowledge and does not lead to a change in behavior. Experiential learning on the other hand represents the personal involvement of the learner. Because the experience becomes internalized and assimilated into the persons being, it will bring about a change in behavior or a modification of perception.

A similar kind of dicotomy can be seen in the work of Ausubel (1967). He too indicates two kinds or types of learning; rote and meaningful verbal learning. Ausubel views rotely learned materials as "discrete and relatively isolated entities which are only relateable to cognitive structure in arbitrary, verbatim fashion." He goes on to note that rotely learned material is more "vulnerable to forgetting" [p. 209]. Ausubel contrasts this to what he terms meaningful verbal learning. He defines this as a kind of "learning which takes place when potentially meaningful verbal material is substantively related to or subsumed under an individual's existing knowledge in a non-arbitrary and non-verbatim fashion so that new meanings are acquired and made more available."

Gagne (1965a) differs from a number of investigators in that he does not focus on the "type" of learning, but rather the "change in capability" [p. 165]; the learner will acquire as a result of a specific experience. The emphasis in the Gagne model is on performance, not type. Words like cognitive, experiential, rote, or meaningful verbal learning only describe a certain type of learning, not a resultant change in behavior. Gagne has identified six kinds of performance. They are:

1. Specific responding
2. Changing (motor and verbal)
3. Multiple discrimination
4. Classification
5. Rule solving
6. Problem solving

Whatever theoretical stance one may take in respect to a given position on learning, the time has come for investigators "to stop inquiring whether one mode of presentation is as good as another" (Siegel and Siegel, 1967, p. 261). For teacher educators, such a conclusion has far reaching significance. Competency-based teacher education makes use of such knowledge by allowing the individual to use the particular learning style that is coincident with his needs. Those concerned with the training of teachers cannot continue to lecture pre-service teachers on discovery learning and individualization of instruction. If transfer from the pre-service experience to the classroom is ever going to take place, it is imperative that the program allow for individual differences.

In addition to providing a program that allows for individual differences, teacher educators are beginning to focus on specific goals and objectives. For this they have turned to the ideas of curriculum theorists that see the need to express learning outcomes in behavioral terms.

As a result of the work of Tyler (1950), Popham (1969) and Gagne (1965a), there has been a movement toward attempting to describe what students will be able to do as a result of instruction. They argue that if learning is to be defined as a change in behavior, a teacher should be able to specify the desired change and determine if indeed the learner has changed his behavior.

In the simplest terms, a behavioral objective specifies how the learner will be different at the end of an episode of instruction. Popham (1969) provides a formal definition in stating that a behavioral objective is an instructional goal that describes an "observational behavior or product which is a consequence of learner behavior" [p. 23]. Once a teacher can specify a given behavioral objective, he has a powerful tool to determine readily whether or not the student has been successful in achieving the specified objective. No longer must the teacher be bound to a paper and pencil test for evaluation. One can set up situations and observe the presence or absence of the specific behaviors of the learners.

For example, a frequently given objective of elementary science is to provide the young child with experiences to enhance his appreciation of the natural world. This is a legitimate and laudatory objective of any elementary science program. Very few teachers would find disagreement with it; yet many teachers will give a fifty-item short-answer examination to determine the extent of the "appreciation" the student has achieved. Instead of stating behaviorally what a student who appreciates the natural world will be like, teachers tend to focus on trivial facts as a measure of appreciation. If we are truly interested in appreciation, it is important for the teacher to try to structure situations where he can observe the learner and determine if he is demonstrating the necessary behaviors that meet the criteria of the objective.

Critics of the use of behavioral objectives such as Atkin (1968b) see five basic faults in their use. The first of these is concerned with the level of specificity of a given objective. Even proponents of the use of behavioral objectives voiced concern over becoming too rigid in specifying the outcomes of instruction. Popham (1969) notes that the need to describe the conditions under which the behavior takes place and level of proficiency is unnecessary. He indicates that these items are "worthwhile additions to a statement of objectives, the most crucial part of the objective for instructional purposes is the description of the learner behavior change."

Eisner (1969) carries the level of specificity one step further by defining two types of objectives. There are those objectives that describe pupil behavior and there is behavior displayed in the context of a given situation. The former he calls instructional objectives and the latter expressive objectives. Eisner defines the expressive objective as an "educational encounter." "It identifies a situation. . ., a problem. . ., a task. . ., but it does not specify what from the encounter situation, problem, or task they (the students) are to learn. Expression objectives serve as a theme, not a terminal behavior. In the expressive context, the product is likely to be as much a surprise to the maker as it is for the learner who encounters it" [p. 15]. For example, if we wish prospective teachers to develop an empathy to the unique needs of the inner city child with respect to science, a teacher education program could have as an expressive objective that the preservice teacher spend some time teaching elementary science in an urban school.

A second criticism of the use of behavioral objectives is that not all learning is observable. This may be true if teachers continue to use traditional means of evaluation. It is important to create situations where learning does become observable. If learning is truly internalized, it will be observable. The process of teacher education should train prospective teachers in new methods of not only how to look, but also where to look.

A third objection voiced by some critics is that the formulation of behavioral objectives becomes like teaching for the test. This will be true if teachers treat the objective as a test item. The use of behavioral objectives is a two-way street; they are equally as important for the teacher as for the student. The attainment of a given objective should not be viewed as getting a correct answer on an examination. If a student does not reach a stated objective, he should not be viewed as having failed a test item. The teacher must evaluate why the student did not exhibit the desired behavior, and then provide alternative means so that learning can take place. The onus is on the teacher to determine why the learner has not reached the objective and what can be done to facilitate his reaching it. It may be necessary to reevaluate the objective in light of the learners needs and experiences.

A fourth objective is directed toward the lack of work that has been done in respect to the use of behavioral objectives in the affective domain. It is true that the majority of work has been in the cognitive domain, but this is not reason enough to dismiss the use of behavioral objectives. Professional educators must assist teachers in developing new techniques in evaluation that will be directed toward the affective domain. Attitudes and values could be operationalized into observable behavior.

For example, if a young child asks a teacher how deep he should plant his seeds, the teacher should encourage him to suggest ways on how to answer his own question. A teacher in such a situation should continue to observe the child to determine if he begins to design his own investigations to answer his questions without first coming to the teacher. By utilizing such a procedure, children will begin to trust themselves as a source of knowledge, not the teacher.

A final but often cited criticism of behavioral objectives is that it will prevent the use of spontaneity in the classroom. It is thought that teachers will become riveted to a specific goal and not capitalize on those moments when the classroom situation takes an unexpected and unplanned turn. One does not need behavioral objectives to have teachers become rigid. How often do we hear teachers speak of having to get through a given unit of work or get a class ready for the next grade level? Behavioral objectives should not be viewed only as products of instruction. Teachers should be trained to make use of rare moments when the unexpected happens in the classroom. These moments should be seen as alternative means to an end, not new ends unto themselves.

Competency-based teacher education makes use of behavioral objectives to communicate to the prospective teacher exactly what is expected of him. How often are students involved in determining the goals toward which they are working and have to wait for an examination to "know" what the teacher wants? The use of behavioral objectives in competency-based teacher education programs publicly indicate what the learner will be like as a result of instruction. By using behavioral objectives, evaluation becomes an integral part of the teachers' growth, not simply a final examination that tests the acquisition of knowledge.

Systems Analysis

Teacher education institutions have traditionally prepared teachers based on the dictates of state certification offices. The question of what kind of teacher does a given institution want, or more important, what kind of teacher does the society need, is in reality nothing more than structuring programs around a specified sequence of courses. Certification requirements are slow to change and we live in a rapidly changing society. Traditional programs have generally been unresponsive to these changes. Cooper and Weber (1971) note that "the rapid societal changes we are now experiencing require teacher education institutions to be far more responsive than ever before" [p. 6].

It has become obvious from the research related to teacher effectiveness that a good teacher is not so much a function of what a teacher knows but how he can use the knowledge. An outgrowth of such a perspective has caused teacher educators to think about the purposes or goals of a given program. Questions of what kind of teachers are needed, what processes or means will be necessary to achieve the stated goals, and what organizational components have to be designed to bring about the desired outcomes?

A consideration of the three elements of purpose, process, and components has brought teacher education into the realm of systems theory. Once teacher educators begin viewing the training of teachers in terms of desired products, it becomes necessary to examine that product as part of a total system. It is impossible to isolate the goals from the processes from the components.

Cooper and Weber (1971) define a system as a "collection of interrelated and interacting components which work in an integrated fashion to attain pre-determined purposes" [p. 8]. LeBaron (1969) provides a broader perspective by indicating a system "as an orderly approach for first defining and describing a universe of interest (and the significant factors and their interrelationships within that universe); and second, determining what changes in that universe will cause a desired effect" [p. 10].

Both definitions have as a commonality the concept of a desired outcome or product. The "products" of a given system are the teachers who graduate from a teacher education program. Cooper and Weber (1971) believe that "the primary measure of the program's success is whether or not these teachers possess the knowledge, skills, and attitudes which the program had as its goals" [p. 4].

It is for this reason that evaluation becomes an absolute necessity. The information derived from the evaluation is used to make necessary modifications in the goals, processes, or components of the program. By using a system approach to teacher education, a given program becomes responsive to the changes and needs of the society.

Cooper and Weber (1971) state that "in a systems approach, the components of a program must be derived from it objectives; they are designed specifically to facilitate the achievement of the program's objectives" [p. 7]. It is for this reason that objectives cannot be stated vaguely or imprecisely since the design of the processes and components is dependent upon the objectives of the program. The use of behavioral and expressive objectives makes it possible to determine whether the processes and components of a given program are accomplishing what they were designed to accomplish.

Operational Structure of Competency-Based Teacher Education Programs

The operational unit of a competency-based teacher education program is the instructional module. An instructional module is a set of learning activities intended to facilitate the student's achievement of an objective or set of objectives. The use of modules enhances the possibilities for self-pacing, independent study, and individualization.

Arends, Masia and Weber (1971) offer three advantages of the modular approach of competency-based programs to traditional programs in teacher education:

1. Because in competency-based teacher education the competencies to be acquired by the student and the criteria to be applied in assessing the competencies of the student are made explicit, the student is fully aware of what is expected.
2. Because time varies for a given student to complete a module, competency-based programs allows for self-pacing. In traditional programs, students are lock-stepped by time.
3. Traditional programs tend to emphasize entrance requirements, whereas the use of modules in competency-based programs emphasize exit requirements.

Arends, et al. (1971) suggest that there are two basic modular formats. One type is a module based on a single objective or at most, two related objectives, a modular cluster and finally a program (Table 1). A second structure is a module based on a cluster of objectives, a component and finally a program (Table 2). It is the latter format that will be used in this dissertation.

In the multiple objective-one module program structure, instructional modules are designed around a group of related objectives. The sum total of the related modules form what is termed a component. In the case of this study, the component is science education. A group of components that have a common purpose, i.e., the preparation of teachers is a total program in teacher education.

Table 1

Total Program

	COMPONENT A	COMPONENT B	COMPONENT C	COMPONENT D	COMPONENT N
Module	Single Objective				
Module Cluster					

One objective--one module program structure.

Table 2

Total Program

	COMPONENT A	COMPONENT B	COMPONENT C	COMPONENT D	COMPONENT N
Module	Multiple Objectives				

Multiple objectives--one module program structure.

CHAPTER IV

METHODOLOGY

Description and Selection of Material

To arrive at the specific competencies, three elementary science programs, supported by the National Science Foundation, were analyzed. The three programs were: (1) the Elementary Science Study (ESS), (2) the Science Curriculum Improvement Study (SCIS), and (3) Science--A Process Approach (SAPA). The three were chosen because they are the most widely utilized elementary science programs and each of the programs has a unique perspective on the nature of science, how children learn, and the role of the teacher.

Although all three programs represent diverse theoretical considerations, they possess certain commonalities from which specific teacher competencies can be derived. These commonalities include:

1. An emphasis on the investigative nature of science;
2. A conviction that the learner should be actively involved in the investigative process;
3. An emphasis on independent learning with opportunities to explore alternative means of inquiry;
4. An attempt to structure the sequence of the instruction of materials within the foundations of contemporary viewpoints on intellectual growth;
5. An articulated and integrated program of instruction.

The following overview of the three programs will focus on five parameters:

1. The state objectives of the program;
2. The nature of science conceived by the program;
3. The programs conception of how children learn;
4. The role of the teacher; and
5. A description of the units selected for analysis from each program.

The Elementary Science Study

The ESES is a K-6 curriculum that has been developed by the Educational Development Corporation. The program consists of some fifty-four self-constrained, non-graded, non-sequential units. The units include the biological and physical sciences as well as some mathematics.

Stated Objectives

The following statement of the ESS objectives is from the Seventh Report of the International Clearinghouse on Science and Mathematics Curricular Developments 1970, edited under the direction of J. David Lockard.

> Primarily, ESS hopes to develop more meaningful science materials for use by children in the form of units which schools can arrange in a variety of sequences to meet their own requirements. The program is a highly individual, experimental one in which all children have access to materials for open-ended rather than teacher or textbook directed investigations. Careful attention is given to all materials used so that all equipment looks like materials which are normally accessible to children in their own environment and not imposingly "Scientific." A mix of university scientists and master teachers work together in the laboratories and in classrooms to test and revise their ideas before the materials are released for general use in the schools. ESS materials have been used equally successfully

> in middle-class suburban and low socio-economic areas, large cities and small towns, and a great variety of different situations. [pp. 369-370]

Nature of Science

The ESS conceives of science as an extention of the child's environment. There is no specific philosophy for the program. Duckworth (1964) notes that the ESS view of science is working with things, not ideas. Concrete objects are what motivates children to explore and to learn. Rogers and Voelker (1970) indicate that the ESS does not view science as concepts such as "living forms are orderly and complex, matter is electrical in nature, or energy is conserved" [p. 38]. Rather, the ESS believes children should create their own science with the manipulation of objects. Science then becomes a construction of knowledge to explain an individual's reality. Randolph Brown (1968), a former director of the ESS, notes that "things encourage children to ask questions and find their own answers" [p. 33].

It is part of the ESS approach to science to avoid using formal names of things and concepts. A word like "grabiness" is used to describe surface tension in a unit on the physics of water. It is the ESS philosophy to have words "enrich understanding, not interfere with--or substitute for--understanding" (EDC, 1968, p. 4).

How Children Learn

The ESS does not ascribe to a specific theory of psychology of learning (Rogers and Voelker, 1970). The curriculum theorists working on the ESS view children as natural scientists:

> They ask questions and use their senses as well as reasoning powers to explore their physical environments; they derive great satisfaction

from finding out what makes things tick; they like solving problems; they are challenged by new materials or by new ways of using familiar materials" [p. 38].

Duckworth (1964), a psychologist who has worked with the ESS, has indicated that the work of Piaget and Dewey represent a psycho-philosophical framework for the program. ESS emphasizes the child's desire to manipulate objects and to have the objects respond to their manipulation.

Rogers and Voelker (1970) observe that the ESS believes in "allowing children to follow their own inclinations as they explore materials. . . . The thinking behind this is that children learn more when they are doing what they want to do instead of what someone else wants them to do" [p. 38].

David Hawkins (1965), a former director of the ESS, has emphasized the importance of allowing children to "mess about" with materials. This approach permits children to learn different things and to learn at different rates.

Role of the Teacher

To be an effective ESS teacher, one must be willing to trust children. The teacher must see the child as having the ability for learning and believe that he learns best from his own activity. Rogers and Voelker (1970) note that the teacher's role in an ESS classroom "is one of consultant, guide, and catalyst."

The ESS teacher must be aware that "children's science is another culture" (Hein, 1968). There is a child's view of biology and physics. Teachers of ESS are encouraged not to have pre-conceived notions about right or wrong responses. Science is an attempt to explain reality; and a child's reality is quite different from an adult's" [p. 1].

The ESS feels it is important to develop materials for the development of the whole child. It is therefore, important for an ESS teacher to facilitate an environment that cultivates the social-emotional growth as well as the intellectual growth of the child.

Units from the ESS Used for the Competency Analyses (Lockard, 1970, pp. 571-578)

Behavior of Mealworms - stimulates children to ask questions about the observable behavior of an unfamiliar animal.

Growing Seeds - a unit that gives children an opportunity to become acquainted with asking questions and devising ways to find their own answers.

Rocks and Charts - encourages children to look closely at the characteristics of rocks.

Where is the Moon? - an informal introduction to observational astronomy.

Daytime Astronomy - suggest ways to help children organize their observations of familiar phenomena and changes in the sky throughout the year.

Science Curriculum Improvement Study

The SCIS is a K-6 curriculum project established in 1962 under the direction of Dr. Robert Karplus at the University of California, Berkeley.

Stated Objectives

The following statement of the SCIS objectives is from the Seventh Report of the International Clearinghouse on Science and Mathematics Curricular Developments 1970, edited under the direction of J. David Lockard.

> SCIS usually capsulizes its purposes as the development of scientific literacy. But it is important to delineate exactly what is meant by the term, and how the staff hopes to achieve this goal. An important meaning of scientific literacy is sufficient knowledge and understanding of the fundamental concepts of both the biological and physical sciences for effective participation in twentieth century life. A second implication of scientific literacy is the development of a free and inquisitive attitude and the use of rational procedures for decision-making. In the SCIS program, children learn science in an atmosphere of intellectual freedom, where their own ideas are respected, where they learn to test their ideas by experiment, and where they learn to accept or reject ideas, not on the basis of some authority, but on the basis of their own observations. Ideally, some of these experiences will carry over to other areas of life and allow children to make decisions on a more rational basis after weighing the factors or evidence involved more objectively. Each unit of the SCIS program presents activities which lead to the understanding of important scientific and process-oriented concepts. The sum of these concepts may be considered a sound base from which the scientifically literate person may seek answers to his questions. [p. 533].

Nature of Science

The SCIS stresses "the fact that the conceptual framework is an essential part of science. . . ." [Karplus and Their, 1966, p. 40]. Through a system of properly guided lessons, children are taught the basic concepts of science that can be used to explain natural phenomena. The SCIS sourcebook (1968) indicates that the "conceptual structure of science consists of the generalizations and relationships that have been developed over the centuries through the use of scientific modes of inquiry" [p. 18].

The concepts of science are developed in the SCIS program via a hierarchical level of abstractions. First level abstractions are concerned with the concepts of matter. Second level abstractions are the conceptions of interaction. Third level abstractions deal with the concepts of energy. Karplus and Their (1966) indicate:

> The abstractions on the earlier levels have to be grasped before ones on the later levels can become meaningful. Each abstraction can be illustrated on its own level, but it is further enriched by illustrations on the succeeding levels" [p. 43].

The SCIS follows six principles to guide the students to the particular concepts (Karplus and Their, 1967):

1. Children need direct experiences with phenomena;
2. Children should engage in investigations;
3. The child develops his own conceptual structure of science;
4. Guidance and discussion are an integral part of the program;
5. Science activities lead children to additional science experiences;
6. Scientific statements are considered to be tentative in nature.

How Children Learn

Thomson and Voelker (1970) note that the SCIS program makes three assumptions regarding the psychological framework of the child and science:

1. The child's elementary school years are a period of transitions as he continues to explore the world he began in infancy;
2. He develops confidence in his own ideas;
3. He builds abstractions with which he interprets the world.

Utilizing this framework, the developers of the SCIS drew upon their interpretation of the work of Piaget to build a program. The SCIS is developmental in nature. It follows the stage theory of intellectual development advanced by Piaget. Early school experiences in the SCIS program are primarily concrete and manipulative experiences. The later units become progressively more abstract. The units build on one another to form a conceptual view of science.

The Role of the Teacher

The structure of the SCIS program places a heavy emphasis on the role of the teacher. The developers believe that the teacher should provide substantial guidance and help with discussion.

The three phase nature of SCIS lessons, i.e., exploration, invention, and discovery, allows the teacher to become an active guide. By having such a role, it is believed by the SCIS that erroneous ideas will be circumvented. Detailed instructions are provided in teacher's guides to assist in the processes of guided discovery.

Karplus and Their (1967) summarize the role of a SCIS teacher:

1. Teacher's do not tell children about science; rather she observes and offers leadership;
2. Conceptual inventions are provided by the teacher when necessary, but are always followed by extensive opportunities for discovery;
3. Teacher's synthesize the classroom needs of children and the discipline called science. [pp. 96-97]

Units From the SCIS Used for the Competency Analysis (Lockard, 1970, pp. 534-536)

Organisms - Children become familiar with some of the requirements for life as they set out seeds and watch the growth of plants. This experience is extended when the class builds aquaria with water plants, fish and snails.

Life Cycles - The investigation of ecosystems begun in Organisms is continued in Life Cycles. The unit, however, focusses on individual organisms, which alone show the characteristics of the phenomenon we call "life."

Populations - The children's attention in this unit is directed toward populations of organisms rather than to individual plants and animals.

Environments - The children observe and isolate environmental factors that effect the survival of organisms.

Science--A Process Approach

SAPA is a K-6 elementary science program that has been developed by the Commission on Science Education of the American Association for the Advancement of Science.

Stated Objectives

The following statement of SAPA objectives is from the Seventh Report of the International Clearinghouse on Science and Mathematics Curricular Developments 1970, edited under the direction of J. David Lockard.

> Science--A Process Approach is designed to present instruction which is intellectually stimulating and scientifically authentic. It is based on a belief that the scientific approach to gaining knowledge of man's world has a fundamental importance in the general education of every child. Instructional materials of Science--A Process Approach are prepared for the teacher, while kits of materials are available for use by the children. Topics covered sample widely from the various fields of science, including some exercises in mathematics and the social sciences. The exercises are ordered in a sequence of instruction to provide a developmental progression of increasing competence in the processes of science. Each exercise is designed to achieve clearly stated objectives. Methods for evaluating pupil achievement and progress are an integral part of the program. [p. 524]

Nature of Science

The designers of SAPA place a heavy emphasis on the process aspect of science rather than the product. Kessen (1965) indicates that "science is more than a body of facts, a collection of principles, and a set of machines for measurement; it is a structured and directed way of asking questions" [p. 4]. For SAPA, content is viewed as a vehicle for the specific processes.

During the primary grades, SAPA stresses the following processes: Observing, Time/Space Relationships, Classifying, Using Numbers, Measuring, Communicating, Predicting, and Inferring.

For the advance grades, the following processes are considered: Controlling Variables, Interpreting Data, Formulating Hypothesis, Defining Operationally, Experimenting.

1. The scientists' behaviors in pursuing science constitute a highly complex set of intellectual activities which are, however, analyzable into simpler activities.
2. These intellectual activities (processes) are, as most scientists would agree, highly generalizable across scientific disciplines.

3. These intellectual activities of scientists may be learned, and it is reasonable to begin with the simplest ones and build the more complex activities out of them, since this seems to be in fact, the way they are organized.
4. Accordingly, one can construct a reasonable sequence of instruction which aims to have children acquire process skills, beginning with simple kinds of observation, and building progressively through classifying, measuring, ...
5. At the end of such instruction, the student will not necessarily know anything which can be identified as physics, or chemistry, or biology, or geology. . . . Such a student should be able to learn any given science, in terms of its theoretical structure, in about half the time that it would otherwise require. [pp. 4-5]

How Children Learn

The SAPA program is primarily associated with the work of psychologist Robert Gagne. It is his contention that SAPA is in the middle between the concept view of the SCIS and the creativity approach advanced by the ESS.

The psychological principle central to the SAPA program is that children should "learn generalizable process skills which are behaviorally specific, but which carry the promise of broad transferability across many subject matters" (Gagne, 1965b, p. 4).

Central to Gagne's theory is his hierarchical view of learning. As previously noted, Gagne does not view inquiry or problem-solving as a process; rather as a terminal acquisition of knowledge. It is for this reason that the SAPA program is organized on the progressive building of complex intellectual processes from simpler ones.

Each of the SAPA processes is designed around a carefully planned set of exercises that will form the foundation, or "pre-requisite knowledge" for higher level processes. The exercises in each grade level are ordered on the basis of complexity of behaviors which the children are to acquire.

The designers of SAPA indicate their psychological position by noting (AAAS 1965):

> The implications of modern psychological studies of learning and transfer of training are clearly to the effect that high degrees of transfer or generalizability are not produced by practice on a narrowly defined task, nor on a series of such tasks, regardless of how intensive such practices may be. Recent studies in conceptual development in children also bear out the thesis that the growth of scientific concepts and logical thinking are related to a great deal more than mere practice of procedures. [p. 11]

The two main conditions of the learning situation in the SAPA program are:

1. Practice on a wide variety of materials, in a wide variety of situations; and
2. The arrangement of the learning situation should reflect the needs and learning levels of the learner; not outside stimuli.

<u>The Role of the Teacher</u>

The role of the teacher is very specific in the SAPA program. She is to provide the child with the specific experiences that will lead to a given process competency. After the child has participated in the experience, the teacher evaluates with a competency measure to determine if the child has achieved the objective.

The teacher must constantly focus on the process involved in an experience, not the content. For example, as children are observing an expanding balloon for the purpose of learning how to communicate, the teacher must refrain from becoming concerned that each child knows what caused the balloon to increase in size. The teacher's role is to focus attention on how well each child is able to communicate what changes he has observed. SAPA teachers are constantly reminded to guard against the tendency to emphasize facts rather than process.

Teachers are encouraged to engage in the activities with the children. The AAAS (1970b) has found that successful teaching of SAPA depends upon the teacher's own competence in the science process. The designers of the program indicate that "individual demonstration of competence is an essential part of the teacher education program" [p. 14].

Process From the SAPA Used for the Competency Analysis (AAAS, 1971)

1. Observing - Beginning with identifying objects and objects-properties, this sequence proceeds to the identification of changes in various physical systems, the making of controlled observations, and the ordering of a series of observations.
2. Classifying - Development begins with simple classifications of various physical and biological systems and progresses through multi-stage classification, their coding and tabluation.
3. Communicating - Development in this category begins with bar graph descriptions of simple phenomena, and proceeds through describing a variety of physical objects and systems, and the changes in them to a construction of graphs and diagrams for observed

results of experiments.

4. Predicting - For this process, the developmental sequence progresses from interpolation to extrapolation in graphically presented data to the formulation of methods for testing predictions.

5. Inferring - Initially, the idea is developed that inferences differ from observations. As development proceeds, inferences are constructed for observations of physical and biological phenomena, and situations are constructed to test inferences drawn from hypotheses.

6. Formulating Hypotheses - At the start of this sequence, the child distinguishes hypotheses from inferences, observations, and predictions. Development is continued to the stage of constructing hypotheses and demonstrating tests of hypotheses.

7. Interpreting Data - The sequence begins with descriptions of graphic data and inferences based upon them, and progresses to constructing equations to represent data, relating data to statements of hypotheses, and making generalizations supported by experimental findings.

8. Controlling Variables - The development sequence for this integrated process begins with identification of manipulated and responding variables in a description or demonstration of an experiment. Development proceeds to the level at which the student, being given a problem, inference or hypotheses, actually conducts an experiment, identifying the variables, and describing how variables are controlled.

9. Experimenting - This is the capstone of the intergrated processes. It is developed through a continuation of the sequence for controlling variables, as well as the activities of stating problems, constructing hypotheses, and carrying out experimental procedures.

Limitations and Assumptions

The following represent the limitations and assumptions of the analysis of the three elementary science programs used in the design of the competency-based learning modules.

1. The three selected elementary science curricula provide an adequate model for the design of a competency-based teacher education program.
2. The natural history format will include the content areas of astronomy, meteorology, geology, botany, zoology, and ecology.
3. Competency objectives in the guidelines of Attitudes Toward Science and Continuous Learning will be derived directly from the AAAS Report on Pre-service Elementary Science Education. Competencies in Attitudes Toward Science and Continuous Learning are implied as necessary for the teacher in the three curricula, but not specifically stated.
4. The reaction from the panel of experts to the competencies will be used as a judgmental validation. No empirical or standard validation procedures will be used.
5. Reactions to the modules from pre and in-service teachers will be directed toward the degree of acceptability of the modules,

not to achievement of the stated competencies.

6. The hierarchical arrangement of the competencies reflect the writer's subjective analysis.

7. Whereas the arrangement within the AAAS guidelines represents a sequential vertical ordering of behavior, the five guideline criteria under which the competencies are subsumed can be arranged in a horizontal fashion to design modules.

Procedure

Preliminary Analysis

All of the previously cited units within the three identified curriculum projects were systematically reviewed. From these units, possible competencies were extracted and stated in behavioral terms. The units from the SCIS and SAPA presented no problem because the programs' objectives are stated in the teacher guides as behavioral objectives. Because of the nature of the ESS, objectives are not specifically indicated. A method suggested by Nichodemus (1968, 1970) was used to change ESS implied objectives into behavioral terms. Nichodemus suggests using the action words of SAPA to construct behaviors from ESS units. The action words are: identifying, distinguishing, constructing, naming, ordering, describing, stating a rule, applying a rule, demonstrating, and interpreting.

Competency Hierarchy Formation

Once all possible objectives were stated in behavioral terms, they were systematically categorized within the five AAAS guidelines.

Additional objectives were formulated in the area of Attitudes Toward Science and Continuous Learning. These objectives were derived directly from the AAAS Report on pre-service elementary science education (1970). A number of objectives were deleted because they were beyond the scope of the guideline criteria or were thought by the investigator to be trivial for the formation of a competency-based teacher education program. A comparison of Tables 3-5 and Tables 6-10 will indicate to the reader the deleted objectives.

Utilizing Nichodemus' (1968, 1970) procedure, each of the competency objectives were ordered into a sequential hierarchy of behavior. According to a procedure outline by Arends, et al. (1971), the five AAAS guidelines were assigned a three-letter code, and the competencies were number-coded and then arranged into a hierarchy consisting of two levels. Level I competencies were general abilities; Level II competencies were behaviorally stated objectives that would contribute to the achievement of the competency described on Level I.

Judgmental Validation of Competencies

To provide a judgmental validation of the Level I and Level II competencies, they were sent to fifty persons that the writer deemed to have expertise in elementary science education. The fifty, making up a panel of experts, were selected from the participants of the AAAS conference that designed the guidelines. A representative selection was made from college level science educators, elementary science supervisors, and elementary school administrators. A cover letter (Appendix A) was sent explaining the purpose of the mailing and a response sheet to two questions.

The questions were (Appendix A):

1. Does the competency reflect the stated guidelines it is subsumed under?
2. Is the competency necessary to teach the new elementary school science programs?

A follow-up letter (Appendix A) was sent to those who did not respond within a period of six weeks.

Modular Design

A final hierarchy competency list was formulated based on the panel of experts responses to the two questions and to the open-ended reaction sheets. Any competency receiving less than fifty percent affirmative responses for either question was deemed by the writer as sufficient evidence not to be included in the final competency list.

Ten modules (Appendix B) were designed utilizing the final hierarchy competency list. The hierarchies were used to form a sequenced pattern of instruction. Following the Level I and Level II competencies, specific performance objectives were stated which would indicate the acquisition of the competency.

Modular Validation

A two phase procedure was used to provide reaction to the ten modules:

1. A group of pre-service elementary education majors were asked on a voluntary basis to participate in the modules. Upon completion of the modules, the students were requested to complete an evaluation form (Appendix C).

2. The modules were sent to thirty in-service teachers using one of the three curriculum projects. Ten to SCIS teachers, ten to ESS teachers, and ten to SAPA teachers. They were asked to read through the modules and to complete an evaluation form (Appendix D).

Results

Preliminary Analysis

1. From SAPA, twenty-five competency objectives were initially selected (Table 3).
2. From the ESS, thirty-seven competency objectives were initially selected (Table 4).
3. From the SCIS, fifty-eight competency objectives were initially selected (Table 5).

Competency Hierarchy Formation

1. The five AAAS guidelines were assigned the following three letter code:

Scientific Inquiry	--	SIN
Attitudes Toward Science	--	ATS
Scientific Knowledge	--	SCK
Processes of Science	--	PRS
Continuous Learning	--	CLT

2. Level I competencies were coded by a three-digit designation followed by a decimal and two zeros. Level II competencies were coded by a three-digit designation followed by a decimal point and a two-digit designation for each subsumed competency objective. (Tables 6-10)

Judgmental Validation of Competencies

1. Of the fifty persons selected to serve as a panel of experts, twenty response sheets to the opinion questionnaire were returned. Two of the twenty were filled out incorrectly and two were returned blank. The final panel consisted of sixteen members. Since the panel was to provide a source of professional opinions other than the author's, the thirty-two percent return was viewed as being sufficient. Results to the two questions are on Tables 11-15.
2. For all the competencies, a majority of the panel indicated affirmatively that a stated competency reflected the guidelines it was subsumed under.
3. Twenty-eight competencies were indicated by a majority of the panel as not to be necessary to teach the new elementary science curricula (Table 16). There were twenty-three from Scientific Knowledge, two from Continuous Learning, and three from Attitudes Toward Science.

Modular Design

1. The final competency hierarchy for the five guidelines with revised code numbers are shown on Tables 17-21.
2. The ten modules formulated from these competencies are:

   Module 1 - Aquaria
   Module 2 - Classification
   Module 3 - Daytime Astronomy
   Module 4 - Growing Seeds
   Module 5 - Inquiry Investigation for Children
   Module 6 - Letter to the Editor

Module 7 - One Square Foot Field Trip
Module 8 - A Question About the Weather
Module 9 - Story in the Rocks
Module 10 - Variation

3. The completed modules with competencies and performance objectives can be found in Appendix B.

Modular Validation

1. Pre-service responses - During a five-week period, eighty-six modules were completed. The results of the evaluation are summarized on Tables 22 and 23.

   Forty-three of the modules were completed by college level juniors, twenty-nine by seniors, and fourteen by graduate students. The mean number of science credits for all of the students was 8.80 and ranged from three to eighteen credits. Scale three, which was concerned with how much the students enjoyed participating in the modules, had a mean score of 4.34 for all eighty-six responses. The module with the lowest rating was Aquaria with a score of 3.00 and the module with the highest rating was the Inquiry Investigation for Children with a mean of 4.50. Scales one and two which were concerned with the students' interest level in science and competency to teach elementary school science had means of 3.40 and 3.16 respectively.

2. In-service responses - Twenty-five in-service teachers responded to the questionnaire on the ten modules. The results are summarized on Tables 24 and 25.

The mean number of years teaching for the twenty-five teachers was 8.40 years. The mean number of science credits was 8.88. Seven teachers using the SCIS responded to the questionnaire had a mean of 4.57 on a scale of one to five related to an overall reaction to the ten modules. Eight ESS teachers responded with a mean of 4.88 to scale one. Nine teachers using SAPA indicated a mean of 4.38 for scale one.

Table 3

Initially Selected Competency Objectives
From Science: A Process Approach

Demonstrating the use of a chart to record weather conditions.
Describing a behavior in terms of stimulus and response.
Distinguishing between the stimulus and response in the observed behavior of animals.
Ordering the germination rates of various seeds and seedlings from fastest to slowest.
Identifying and naming properties or characteristics on which to base a single stage classification system.
Constructing and demonstrating the use of a single stage system for classifying objects or organisms that appear similar in appearance.
Constructing and demonstrating the use of a single stage system for classifying pictures of various animals.
Constructing and demonstrating the use of a table of classification for a collection of materials that uniquely identifies each material in the collection.
Distinguishing between observations that support a hypothesis and those that refute it.
Constructing a graph of the measured changes in seeds and seed sprouts.
Constructing a bar graph from a frequency distribution.
Describing the observed results of carrying out a procedure for testing conditions that affect plant growth.
Describing a sequence of procedures for testing conditions that affect plant growth.
Identifying and naming the scale of a map.
Identifying and naming locations on a simple map.
Constructing a map on a larger or smaller scale than the original map.
Describing a sequence of events in an inquiry investigation.

Table 3 (continued)

Applying the rules of interpretation and extrapolation to bar graphs to formulate predictions.
Constructing a revision of a prediction on the basis of additional data.
Constructing tests of predictions.
Identifying statements that are inferences.
Distinguishing between statements of observation and statements that are plausible explanations.
Demonstrating that inferences may need to be alterned on the basis of additional information.
Describing observations which can be used to test an inference.
Identifying factors in the environment that may affect the growth and reproduction of an organism.

Table 4

Initially Selected Competency Objectives
From the Elementary Science Study

To determine the places the mealworm is most sensitive to stimuli.

To observe the effect of various stimuli on a mealworm.

To observe the behavior of a mealworm.

To observe how mealworms follow walls.

To observe the behavior of a mealworm in a box.

To observe the habitats of earthworms.

To measure the amount of time a mealworm is in a specific part of a box.

To determine the natural environment of mealworms.

To determine what causes a mealworm to back up.

To construct experiments on the stimulus response of mealworms.

To construct an experiment to see if mealworms can see.

To observe the anatomy of selected organisms.

To determine the environment of earthworms.

To prepare a classroom environment for the earthworms.

To set up an experiment to determine the effects of light, dark, moist, dry, hot, cold.

To observe the mating and reproductive patterns of worms.

To predict possible effects of various stimuli.

To keep an observation notebook.

To participate in a field trip to collect earthworms.

To care and feed earthworms.

To relate observations to predictions.

Table 4 (continued)

To observe the behavioral responses to various stimuli.
To observe the effect of changing environmental variables.
To observe the behavior of selected organisms.
To determine the time difference of moon rise and moon set on a daily basis.
To observe the change in the moon's position during a specific time period.
To measure the moon's position by an arbitrary method.
To predict the moon's position using the arbitrary measuring system.
To predict where the moon will be on a specific date or time.
To predict the moon's shape on a specific date.
To use an almanac to determine moon rise and moon set.
To demonstrate the use of a compass to locate the sun.
To observe the changing length of a shadow on a daily basis and over a period of time.
To describe the nature of the earth-sun relationship to explain changing shadow lengths.
To describe the motions of rotation and revolution.
To observe the characteristics of rocks.
To classify rock according to their characteristics.
To identify the major classes of rocks.

Table 5

Initially Selected Competency Objectives
From the Science Curriculum Improvement Study

To describe seeds and grow plants from seeds.

To state some general requirements for seed germination and plant growth.

To recognize and describe birth, reproduction, death, feeding, growing, and other events in an aquarium.

To identify organisms that eat others in an aquarium.

To use the term "food web" to refer to the feeding relationship among organisms.

To represent a food web with a diagram.

To describe changes in the color of the water in the aquarium.

To propose and test hypothesis about changes in the color of the aquarium water.

To draw conclusions from the data.

To understand the term "habitat" and to use it to refer to a place where an organism lives.

To describe diverse habitats of organisms ordinarily found in the school area.

To predict what would happen if the seeds produced by a plant matured.

To infer biotic potential of animals.

To recognize that early death prevents the fulfillment of biotic potential.

To infer the biotic potential of plants.

To describe differences and similarities among different kinds of seeds.

To recognize the major events in the germination of a seed.

To recognize the parts of a germinating seed.

To identify fruits as a source of seeds.

Table 5 (continued)

To make inferences from the results of experiments.

To set up experiments that might help answer questions about seeds and plants.

To recognize that many seeds are usually contained in a single fruit.

To relate molting to growth.

To describe the differences between growth and development.

To use the term "life cycle" to refer to the series of changes observed as a fly develops from egg to adult and produces eggs.

To use the term "metamorphasis" to refer to change in body form.

To identify the four stages in the life of a fruit fly.

To identify major stages in the life cycle of a frog.

To describe the life cycle of a mealworm.

To observe the effect of crickets on plant populations.

To recognize that increase in size of a population results from the production of offspring.

To recognize that all food chains begin with green plants.

To identify the food relationship among plants, plant eaters, and animal eaters as a food chain.

To recognize that a food web is composed of food chains.

To identify an animal as a plant eater, or animal eater, or a plant and animal eater.

To classify animals as predators or prey, and recognize their relationship.

To devise and carry out experiments that might help to answer questions.

To define a problem and suggest possible answers.

To identify populations of organisms around the school yard.

To recognize that the size of a population can increase or decrease depending partly on environmental conditions.

Table 5 (continued)

To understand the term "population" and use it to refer to a group of plants or animals of one kind in a particular area.

To understand the term "community" and use it to refer to all populations that live and interact in a particular area.

To describe food relationships among populations in a given area.

To control an experiment.

To process data so it becomes more meaningful.

To become familiar with a system of recording growth data.

To examine the normal growth of various plants.

To recognize variation in growth of the same species of plants.

To recognize that organisms respond to factors in their environments.

To investigate the effects of changing the amount of light on plants.

To compare growth rates of different species of plants.

To recognize that different organisms respond to the same environmental factors in different ways.

To use the results of experiments in determining the most suitable habitat for an organism.

To determine a suitable environment for a new organism.

To learn a method of recording changes in organisms and some of the associated environmental conditions.

To recognize the relationship between the changes in the environmental factors and the changes in the organism.

To recognize that changes in the environment caused by one organism can affect another organism.

Table 6

Hierarchy for Scientific Inquiry Competencies

	SCIENTIFIC INQUIRY (SIN)
SIN-001.00	The ability to investigate.
SIN-001.01	To define a problem and suggest possible answers.
SIN-001.02	To devise and carry out experiments that might help to answer questions.
SIN-001.03	To control an experiment.
SIN-001.04	To formulate a system for recording data.
SIN-001.05	To process data so it becomes more meaningful.
SIN-001.06	To distinguish between observations that support a hypothesis and those that refute it.
SIN-001.07	To formulate conclusions.
SIN-001.08	To describe an investigation so it can be repeated by another person.
SIN-002.00	The ability to teach science as inquiry.
SIN-002.01	To teach science using the inquiry approach rather than the demonstration method.
SIN-002.02	To select inquiry techniques consistent with the child's learning ability.
SIN-002.03	To emphasize inquiry learning rather than the memorization of facts.
SIN-002.04	To teach children inquiry skills.

Table 7

Hierarchy for Attitudes Toward Science Competencies

	ATTITUDES TOWARD SCIENCE (ATS)
ATS-001.00	The ability to demonstrate an interest in and a positive attitude toward science.
ATS-001.01	To indicate how the local community has been affected by science and technology.
ATS-001.02	To participate in a local environmental protection group.
ATS-002.00	To encourage pupils to use the inquiry approach when asked a question.
ATS-003.00	To demonstrate an interest in science by reading books and articles not assigned.

Table 8

Hierarchy for Scientific Knowledge Competencies

	SCIENTIFIC KNOWLEDGE (SCK)
SCK-001.00	The ability to describe the conceptual orientation and interaction of the earth, universe, biotic and abiotic world that can be used to explain natural phenomena.
SCK-001.01	To describe the earth-sun-moon relationships to explain seasonality and climatic phenomena.
SCK-001.02	To construct physical and mental models of the origin of the earth, solar system, and universe.
SCK-001.03	To describe the interactions involved in geological processes.
SCK-001.04	To reconstruct the geological history of a local area.
SCK-002.00	The ability to describe the processes of growth and reproduction in plants and animals.
SCK-002.01	To describe differences and similarities among several kinds of seeds.
SCK-002.02	To describe the major events in the germination of a seed.
SCK-002.03	To recognize the parts of a germinating seed.
SCK-002.04	To identify fruits as a source of seeds.
SCK-002.05	To state some general requirements for seed germination and plant growth.
SCK-002.06	To describe the differences between growth and development.
SCK-002.07	To use the term "life cycle" to refer to the series of changes observed in an organism as it develops from egg to adult and produces eggs.
SCK-002.08	To use the term metamorphosis to refer to a change in body form.
SCK-002.09	To identify the four stages in the life cycle of a fruit fly.
SCK-002.10	To identify the major stages in the life cycle of a frog.
SCK-002.11	To describe the life cycle of a mealworm.
SCK-003.00	The ability to describe the interactions that exist among living organisms.
SCK-003.01	To use the term "habitat" to refer to a place where an organism lives.
SCK-003.02	To use the term "population" to refer to a group of plants or animals of one kind in a particular area.
SCK-003.03	To use the term "community" to refer to all populations live and interact within a particular area.
SCK-003.04	To describe food relationships among populations in a given area.
SCK-003.05	To recognize that all food chains begin with green plants.
SCK-003.06	To identify the food relationship among plants, plant eaters, and animal eaters as a food chain.
SCK-003.07	To use the term "food web" to refer to the feeding relationship among organisms.
SCK-003.08	To recognize that a food web is composed of food chains.

Table 8 (continued)

SCK-004.00	The ability to describe observations of living and non-living objects in terms of their physical, chemical, and biological composition, characteristics, and structure.
SCK-004.01	To describe the physical changes a geological system has undergone.
SCK-004.02	To identify the three main classes of rocks.
SCK-004.03	To identify the morphological characteristics of fruit flies, earthworms, frogs, and crickets.
SCK-004.04	To describe the physical and biological processes.
SCH-004.05	The ability to describe the evolutionary and genetic factors involved in plant and animal populations.
SCK-005.00	The ability to describe the evolutionary and genetic factors involved in plant and animal populations.
SCK-005.01	To establish genetic identity of a given seed to a given plant.
SCK-005.02	To describe the effects of variation on the evolution of a species.
SCK-005.03	To describe the relationship of form and function.
SCK-005.04	To describe the relationship of overpopulation and biotic potential.
SCK-006.00	The ability to describe the behavior patterns of an organism.
SCK-006.01	To describe the behavior patterns of mealworms, earthworms and crickets.

Table 9

Hierarchy for Processes of Science Competencies

	PROCESSES OF SCIENCE (PRS)
PRS-001.00	The ability to make empirical observations.
PRS-001.01	To observe the effect of changing environmental variables.
PRS-001.02	To observe the behavior of selected organisms.
PRS-001.03	To observe the anatomy of selected organisms.
PRS-001.04	To observe the effect of stimuli on the behavior of an organism.
PRS-001.05	To observe the life cycle of plants and animals.
PRS-001.06	To observe changes in the sky.
PRS-002.00	The ability to make reasonable inferences when presented with empirical data.
PRS-002.01	To identify statements that are inferences.
PRS-002.02	To describe observations which can be used to test an inference.
PRS-002.03	To distinguish between statements of observation and statements of inference.
PRS-002.04	To make inferences from the results of experiments.
PRS-002.05	To demonstrate that inferences may need to be altered on the basis of additional data.
PRS-003.00	The ability to make predictions based on observable data.
PRS-003.01	To construct tests of predictions.
PRS-003.02	To relate observations to predictions.
PRS-003.03	To construct a revision of a prediction on the basis of additional data.
PRS-003.04	To construct a relationship between two variables that can be used to make predictions.
PRS-004.00	The ability to identify and control variables which may affect the results of an investigations.
PRS-004.01	To identify the factors in the environment that may affect the growth and reproduction of plants and animals.
PRS-004.02	To investigate the affects of varying environmental factors on the growth of organisms.
PRS-004.03	To recognize that changes in the environment caused by one organism can affect another.
PRS-005.00	The ability to measure variables.
PRS-005.01	To measure length in standard and arbitrary units.
PRS-005.02	To measure mass in standard and arbitrary units.
PRS-005.03	To measure volume in standard and arbitrary units.
PRS-0 6.00	The ability to construct and use classification scheme.
PRS-006.01	To identify and name the properties or characteristics on which to base a single stage classification system.
PRS-006.03	To construct and demonstrate the use of a classification scheme for a collection of materials that uniquely identifies each object in the collection.
PRS-007.00	The ability to communicate the procedures and results of an investigation.
PRS-007.01	To describe a sequence of events in an inquiry investigation.
PRS-007.02	To construct a graph based on observational data.

Table 10

Hierarchy for Continuous Learning Competencies

Hierarchy for Continuous Learning Competencies

CTL-001.00	The ability to demonstrate the capacity and disposition for continuous learning.
CTL-001.01	To identify and describe conflicting scientific issues.
CTL-001.02	To obtain information on scientific issues related to education.
CTL-001.03	To identify the interrelationship of science to other areas of knowledge.
CTL-001.04	To identify a weakness in the students own scientific background and provide a way of correcting it.

Table 11

Results of Panel of Experts Opinion Questionnaire on Scientific Inquiry Competencies

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
The ability to investigate	16	16	100.00	0	0	15	13	86.65	2	13.35
To define a problem and suggest possible answers	16	15	93.75	1	6.25	15	13	86.65	2	13.35
To devise and carry out experiments that might help to answer questions	16	15	93.75	1	6.25	15	14	93.33	1	6.67
To control an experiment	16	14	87.50	2	12.50	14	13	92.86	1	7.14
To formulate a system for reading data	16	15	93.75	1	6.25	14	14	100.00	0	0
To process data so it becomes more meaningful	16	15	93.75	1	6.25	15	12	80.00	3	20.00
To distinguish between observations that support a hypothesis and those that refute it.	16	15	93.75	1	6.25	15	14	93.33	1	6.67
To formulate conclusions	15	12	80.00	3	20.00	15	12	80.00	3	20.00
To describe an investigation so it can be repeated by another person	16	11	68.75	5	31.25	15	11	73.33	4	26.67
The ability to teach science as inquiry	13	10	76.92	3	23.08	16	15	93.75	1	6.25
To teach science using the inquiry approach rather than the demonstration method	14	11	78.57	3	21.43	16	16	100.00	0	0

Table 11 (continued)

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
To select inquiry techniques consistant with the child's learning ability	14	11	78.57	3	21.43	16	16	100.00	0	0
To emphasize inquiry learning rather than the memorization of facts.	14	10	71.43	4	28.57	16	16	100.00	0	0
To teach children inquiry skills	14	10	71.43	4	28.57	15	15	100.00	0	0

Table 12

Results of Panel of Experts Opinion Questionnaire
On Attitudes Toward Science Competencies

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
The ability to demonstrate an interest in and a positive attitude toward science	16	16	100.00	0	0	16	15	93.75	1	6.25
To indicate how the local community has been affected by science and technology	16	16	100.00	0	0	16	5	31.25	11	68.75
To participate in a local environmental protection group	16	9	56.25	7	43.75	16	3	18.75	13	81.25
To encourage pupils to use the inquiry approach when asked a question	14	9	64.29	5	35.71	16	14	87.50	2	12.50
To demonstrate an interest in science by reading books and articles not assigned	14	12	85.72	2	14.28	16	7	43.75	9	56.25

Table 13

Results of Panel of Experts Opinion Questionnaire
On Scientific Knowledge Competencies

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
The ability to describe the conceptual orientation and interaction of the earth, universe, biotic and abiotic world that can be used to explain natural phenomena	15	15	100.00	0	0	13	7	53.85	6	46.15
To describe the earth-sun-moon relationships to explain seasonality and climatic phenomena	16	16	100.00	0	0	15	5	33.33	10	66.67
To construct physical and mental models of the origin of the earth, solar system, and universe.	16	16	100.00	0	0	15	6	40.00	9	60.00
To describe the interaction involved in geological processes	16	16	100.00	0	0	15	5	33.33	10	66.67
To reconstruct the geological history of a location	16	16	100.00	0	0	15	4	26.67	11	73.33
The ability to describe the process of growth and reproduction in plants and animals	16	16	100.00	0	0	15	10	66.67	5	33.33
To describe differences and similarities among several kinds of seeds.	16	16	100.00	0	0	15	10	66.67	5	33.33

Table 13 (continued)

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
To describe the major events in the germination of a seed.	16	16	100.00	0	0	15	6	40.00	9	60.00
To recognize the parts of a germinating seed.	16	15	93.75	1	6.25	15	5	33.33	10	66.67
To identify fruits as a source of seeds.	16	16	100.00	0	0	14	5	35.71	9	64.29
To state some general requirements for seed germination. To describe the differences between growth and development.	16	16	100.00	0	0	14	7	50.00	7	50.00
To use the term "life cycle" to refer to the series of changes observed in an organism as it develops from egg to adult and produces eggs.	16	14	87.50	2	12.50	14	4	28.57	10	71.43
To use the term metamorphosis to refer to a change in body form.	16	14	87.50	2	12.50	14	5	35.71	9	64.29
To identify the four stages in the life cycle of a fruit fly.	16	15	93.75	1	6.25	14	3	21.43	11	78.57
To identify the major stages in the life cycle of a frog.	16	15	93.75	1	6.25	14	4	28.57	10	71.43
To describe the life cycle of a mealworm.	16	16	100.00	0	0	14	5	35.71	9	64.29

Table 13 (continued)

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
The ability to describe the interactions that exist among living organisms.	16	15	93.75	1	6.25	14	6	42.85	8	57.15
To use the term "habitat" to refer to a place where an organism lives.	16	15	93.75	1	6.25	14	7	50.00	7	50.00
To use the term "population" to refer to a group of plants or animals of one kind in a particular area.	16	15	93.75	1	6.25	14	7	50.00	7	50.00
To use the term "community" to refer to all populations that live and interact within a particular area.	16	15	93.75	1	6.25	14	7	50.00	7	50.00
To describe food relationships among populations in a given area.	16	16	100.00	0	0	14	7	50.00	7	50.00
To recognize that all food chains begin with a green plant.	16	16	100.00	0	0	14	7	50.00	7	50.00
To identify the food relationship among plants, plant eaters, and animal eaters as a food chain.	16	15	93.75	1	6.25	14	6	42.85	8	57.15
To use the term "food web" to refer to the feeding relationship among organisms.	16	14	87.50	2	12.50	14	5	35.71	9	64.29
To recognize that a food web is composed of food chains.	16	16	100.00	0	0	14	5	35.71	9	64.29

Table 13 (continued)

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
The ability to describe observations of living and non-living objects in terms of their physical, chemical, and biological composition, characteristics and structure.	16	16	100.00	0	0	14	8	57.15	6	42.85
To describe the physical changes a geological system has undergone.	16	16	100.00	0	0	14	4	28.57	10	71.43
To identify the three main classes of rocks.	16	15	93.75	1	6.25	14	5	35.71	9	64.29
To identify the morphological characteristics of fruit flies, earthworms, frogs, and crickets.	16	15	93.75	1	6.25	14	4	28.57	10	71.43
To describe the physical and biological processes.	16	16	100.00	0	0	12	7	58.33	5	41.67
The ability to describe the evolutionary and genetic factors involved in plant and animal populations.	15	15	100.00	0	0	8	4	50.00	4	50.00
To establish genetic identity of a given plant.	16	15	93.75	1	6.25	13	3	23.08	10	76.92
To describe the effects of variation on the evolution of a species.	16	16	100.00	0	0	13	3	23.08	10	76.92

Table 13 (continued)

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
To describe the relationship of form and function.	16	15	93.75	1	6.25	14	7	50.00	7	50.00
To describe the relationship of overpopulation and biotic potential.	15	15	100.00	0	0	13	4	80.77	9	69.23
The ability to describe the behavior patterns of an organism.	16	16	100.00	0	0	14	6	42.85	8	57.15
To describe the behavior patterns of mealworms, earthworms, and crickets.	16	16	100.00	0	0	13	4	30.77	9	69.23

Table 14

Results of Panel of Experts Opinion Questionnaire
On Process of Science Competencies

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
The ability to make empirical observations.	16	16	100.00	0	0	16	16	100.00	0	0
To observe the effect of changing environmental variables.	16	16	100.00	0	0	15	14	93.33	1	6.67
To observe the behavior of selected organisms.	16	16	100.00	0	0	15	14	93.33	1	6.67
To observe the anatomy of selected organisms.	16	16	100.00	0	0	15	10	66.67	5	33.33
To observe the effect of stimuli on behavior of an organism.	16	16	100.00	0	0	15	13	86.65	2	13.35
To observe the life cycle of plants and animals.	16	16	100.00	0	0	15	12	80.00	3	20.00
To observe changes in the sky.	16	15	93.75	1	6.25	16	10	62.50	6	37.50
The ability to make reasonable inferences when presented with empirical data.	16	16	100.00	0	0	16	16	100.00	0	0
To identify statements that are inferences.	16	16	100.00	0	0	16	16	100.00	0	0
To describe observations which can be used to test inferences.	16	16	100.00	0	0	16	16	100.00	0	0

Table 14 (continued)

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
To distinguish between statements of observation and statements of inference.	16	16	100.00	0	0	16	16	100.00	0	0
To make inferences from the results of experiments.	16	15	93.75	1	6.25	16	15	93.75	1	6.25
To demonstrate that inferences may need to be altered on the basis of additional data.	16	16	100.00	0	0	16	16	100.00	0	0
The ability to make predictions based on observational data.	16	16	100.00	0	0	16	16	100.00	0	0
To construct test of predictions.	16	16	100.00	0	0	16	15	93.75	1	6.25
To relate observations to predictions.	16	16	100.00	0	0	16	15	93.75	1	6.25
To construct a revision of a prediction on the basis of additional data.	16	16	100.00	0	0	16	15	93.75	1	6.25
To construct a relationship between two variables that can be used to make predictions.	16	16	100.00	0	0	16	15	93.75	1	6.25
The ability to identify and control variables which may affect the results of an investigation.	16	16	100.00	0	0	15	14	93.33	1	6.67

Table 14 (continued)

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
To identify the factors in the environment that may affect the growth and reproduction of plants and animals.	16	16	100.00	0	0	15	12	80.00	3	20.00
To investigate the effects of varying environmental factors on the growth of organisms.	16	16	100.00	0	0	15	11	73.33	4	26.67
To recognize that changes in the environment caused by an organism can affect another.	16	16	100.00	0	0	15	11	73.33	4	26.67
The ability to measure variables.	16	16	100.00	0	0	16	16	100.00	0	0
To measure length in standard and arbitrary units.	16	16	100.00	0	0	15	14	93.33	1	6.67
To measure mass in standard and arbitrary units.	16	16	100.00	0	0	15	13	86.65	2	13.35
To measure volume in standard and arbitrary units.	16	16	100.00	0	0	15	13	86.65	2	13.35
The ability to construct and use a classification scheme.	16	16	100.00	0	0	16	16	100.00	0	0
To construct and demonstrate the use of a classification scheme for a collection of materials that uniquely identifies each object in the collection.	16	16	100.00	0	0	15	15	100.00	0	0

Table 14 (continued)

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
The ability to communicate the procedures and results of an investigation.	16	15	93.75	1	6.25	15	15	100.00	0	0
To describe a sequence of events in an inquiry investigation.	16	16	100.00	0	0	16	15	93.75	1	6.25
To construct a graph based on observational data.	16	16	100.00	0	0	16	15	93.75	1	6.25

Table 15

Results of Panel of Experts Opinion Questionnaire
On Continuous Learning Competencies

COMPETENCY	COMPETENCY REFLECTS GUIDELINE					COMPETENCY NECESSARY TO TEACH NEW SCIENCE CURRICULA				
	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT	NUMBER ANSWERING ITEM	YES	PER-CENT	NO	PER-CENT
The ability to demonstrate the capacity and disposition for continuous learning.	14	14	100.00	0	0	12	9	75.00	3	25.00
To identify and describe conflicting scientific issues.	16	15	93.75	1	6.25	15	4	26.67	11	73.33
To obtain information on scientific issues related to education.	16	14	87.50	2	12.50	15	6	40.00	9	60.00
To identify the interrelationship of science to other areas of knowledge.	14	14	100.00	0	0	15	9	60.00	6	40.00

Table 16

Competency Objectives: Rejected by Panel of Experts As Necessary to Teach New Elementary Science Programs

CODE	COMPETENCY
SCK-001.01	To describe the earth-sun-moon relationships to explain seasonality and climatic phenomena.
SCK-001.02	To construct physical and mental models of the origin of the earth, solar system, and universe.
SCK-001.03	To describe the interaction involved in geological processes.
SCK-002.02	To describe the major events in the germination of a seed.
SCK-002.03	To recognize the parts of a germinating seed.
SCK-002.04	To identify fruits as a source of seeds.
SCK-002.06	To describe the differences between growth and development.
SCK-002.07	To use the term "life cycle" to refer to the series of changes observed in an organism as it develops from egg to adult and produces eggs.
SCK-002.08	To use the term metamorphosis to refer to a change in body form.
SCK-002.09	To identify the four stages in the life cycle of a fruit fly.
SCK-002.10	To identify the major stages in the life cycle of a frog.
SCK-002.11	To describe the life cycle of a mealworm.
SCK-003.06	To identify the food relationship among plants, plant eater, and animal eater as a food chain.
SCK-003.07	To use the term "food web" to refer to the feeding relationship among organisms.
SCK-003.08	To recognize that a food web is composed of food chains.
SCK-004.01	To describe the physical changes a geological system has undergone.
SCK-004.02	To identify the three main classes of rocks.
SCK-004.03	To identify the morphological characteristics of fruit flies, earthworms, frogs, and crickets.
SCK-005.01	To establish genetic identity of a given seed to a given plant.
SCK-005.02	To describe the effects of variation on the evolution of a species.
SCK-005.04	To describe the relationship of overpopulation and biotic potential.

Table 16 (continued)

CODE	COMPETENCY
SCK-006.00	The ability to describe the behavior patterns of an organism.
SCK-006.01	To describe the behavior patterns of mealworms, earthworms, and crickets.
CLT-001.01	To identify and describe conflicting scientific issues.
CLT-001.02	To obtain information on scientific issues related to education.
ATS-001.01	To indicate how the local community has been affected by science and technology.
ATS-001.02	To participate in a local environmental protection group.
ATS-003.00	To demonstrate an interest in science by reading books and articles not assigned.

Table 17

Final Hierarchy for Scientific Inquiry Competencies

SCIENTIFIC INQUIRY (SIN)	
SIN-001.00	The ability to investigate.
SIN-001.01	To define a problem and suggest possible answers.
SIN-001.02	To devise and carry out experiments that might help to answer questions.
SIN-001.03	To control an experiment.
SIN-001.04	To formulate a system for recording data.
SIN-001.05	To process data so it becomes more meaningful.
SIN-001.06	To distinguish between observations that support a hypothesis and those that refute it.
SIN-001.07	To formulate conclusions.
SIN-001.08	To describe an investigation so it can be repeated by another person.
SIN-002.00	The ability to teach science as inquiry.
SIN-002.01	To teach science using the inquiry approach rather than the demonstration method.
SIN-002.02	To select inquiry techniques consistent with the child's learning ability.
SIN-002.03	To emphasize inquiry learning rather than the memorization of facts.
SIN-002.04	To teach children inquiry skills.

Table 18

Final Hierarchy for Attitudes Toward Science Competencies

ATS-001.00	The ability to demonstrate an interest in and a positive attitude toward science.
ATS-002.00	To encourage pupils to use the inquiry approach when asked a question.

Table 19

Final Hierarchy for Scientific Knowledge Competencies

CODE	COMPETENCY
SCK-001.00	The ability to describe the conceptual orientation and interaction of the earth, universe, biotic and abiotic world that can be used to explain natural phenomena.
SCK-002.00	The ability to describe the processes of growth and reproduction in plants and animals.
SCK-002.01	To describe differences and similarities among several kinds of seeds.
SCK-002.02	To state some general requirements for seed germination and plant growth.
SCK-003.00	The ability to describe the interactions that exist among living organisms.
SCK-003.01	To use the term "habitat" to refer to a place where an organism lives.
SCK-003.02	To use the term "population" to refer to a group of plants or animals of one kind in a particular area.
SCK-003.03	To use the term "community" to refer to all populations that live and interact within a particular area.
SCK-003.04	To describe food relationships among populations in a given area.
SCK-003.05	To recognize that all food chains begin with green plants.
SCK-004.00	The ability to describe observations of living and nonliving objects in terms of their physical, chemical, and biological composition, characteristics, and structure.
SCK-004.01	To describe the physical and biological processes.
SCK-005.00	The ability to describe the evolutionary and genetic factors involved in plant and animal populations.
SCK-005.01	To describe the relationship of form and function.

Table 20

Final Hierarchy for Processes of Science Competencies

	PROCESSES OF SCIENCE (PRS)
PRS-001.00	The ability to make empirical observations.
PRS-001.01	To observe the effect of changing environmental variables.
PRS-001.02	To observe the behavior of selected organisms.
PRS-001.03	To observe the anatomy of selected organisms.
PRS-001.04	To observe the effect of stimuli on the behavior of an organism.
PRS-001.05	To observe the life cycle of plants and animals.
PRS-001.06	To observe changes in the sky.
PRS-002.00	The ability to make reasonable inferences when presented with empirical data.
PRS-002.01	To identify statements that are inferences.
PRS-002.02	To describe observations which can be used to test an inference.
PRS-002.03	To distinguish between statements of observation and statements of inference.
PRS-002.04	To make inferences from the results of experiments.
PRS-002.05	To demonstrate that inferences may need to be altered on the basis of additional data.
PRS-003.00	The ability to make predictions based on observable data.
PRS-003.01	To construct tests of predictions.
PRS-003.02	To relate observations to predictions.
PRS-003.03	To construct a revision of a prediction on the basis of additional data.
PRS-003.04	To construct a relationship between two variables that can be used to make predictions.
PRS-004.00	The ability to identify and control variables which may affect the results of an investigation.
PRS-004.01	To identify the factors in the environment that may affect the growth and reproduction of plants and animals.
PRS-004.02	To investigate the affects of varying environmental factors on the growth of organisms.
PRS-004.03	To recognize that changes in the environment caused by one organism can affect another.
PRS-005.00	The ability to measure variables.
PRS-005.01	To measure length in standard and arbitrary units.
PRS-005.02	To measure mass in standard and arbitrary units.
PRS-005.03	To measure volume in standard and arbitrary units.
PRS-006.00	The ability to construct and use classification scheme.
PRS-006.01	To identify and name the properties or characteristics on which to base a single stage classification system.
PRS-006.03	To construct and demonstrate the use of a classification scheme for a collection of materials that uniquely identifies each object in the collection.
PRS-007.00	The ability to communicate the procedures and results of an investigation.
PRS-007.01	To describe a sequence of events in an inquiry investigation.
PRS-007.02	To construct a graph based on observational data.

Table 21

Final Hierarchy for Continuous Learning Competencies

CODE	COMPETENCY
CLT-001.00	The ability to demonstrate the capacity and disposition for continuous learning.
CLT-001.01	To identify the interrelationship of science to other areas of knowledge.
CLT-001.02	To identify a weakness in the students own scientific background and provide a way of correcting it.

Table 22

Responses to Modules by Pre-Service Teachers

MODULE	NUMBER OF RESPONSES BY GRADE			MEAN FOR SCALE ONE	MEAN FOR SCALE TWO	MEAN FOR SCALE THREE	MEAN FOR SCALE FOUR	MEAN FOR SCALE FIVE
	J	S	G					
1 n=1	0	1	0	2.00	2.00	3.00	3.00	5.00
2 n=13	6	6	1	3.30	3.00	4.53	4.30	4.77
3 n=10	5	3	2	3.80	3.60	4.70	4.40	4.80
4 n=14	6	6	2	3.28	3.14	4.50	4.35	4.36
5 n=6	2	3	1	3.83	3.50	4.83	4.50	4.83
6 n=0	0	0	0	--	--	--	--	--
7 n=14	8	3	3	3.43	3.14	4.71	4.36	4.71
8 n=14	9	4	1	3.07	2.71	4.50	4.36	4.71
9 n=8	5	1	2	3.75	3.50	4.50	4.38	4.62
10 n=6	2	2	2	3.33	3.33	3.67	4.33	3.50

J = Junior, S = Senior, G = Graduate
(Refer to pages 71-72 for corresponding module names and numbers.)

1. On a scale of 1 to 5, rate your present interest level in science.

1	2	3	4	5
DISLIKE				LIKE

2. On a scale of 1 to 5, rate your feeling of competency to teach elementary school science.

1	2	3	4	5
INCOMPETENT				COMPETENT

3. On a scale of 1 to 5, rate your feeling about how much you enjoyed participating in the module.

1	2	3	4	5
DID NOT ENJOY				FULLY ENJOYED

4. On a scale of 1 to 5, rate your level of achievement of the stated competencies.

1	2	3	4	5
NONE ACHIEVED				ALL ACHIEVED

5. On a scale of 1 to 5, rate the potential usefulness of the module in your career as an elementary school teacher.

1	2	3	4	5
USELESS				USEFUL

Table 23

Data for All Modules for All Grades

ABSOLUTE FREQUENCY OF MODULES		FREQUENCY OF SELECTION BY GRADE			SCIENCE CREDITS FOR ALL GRADES		MEAN FOR ALL SCALES FOR ALL MODULES n=86	
		J	S	G	MEAN	RANGE		
1	1	43	29	14	8.80	3-18	1	3.40
2	13						2	3.16
3	10						3	4.51
4	14						4	4.34
5	6						5	4.59
6	0							
7	14							
8	14							
9	8							
10	6							

J = Junior, S = Senior, G = Graduate

Table 24

Responses to Modules by In-Service Teachers

ELEMENTARY SCIENCE PROGRAM	NO. OF RESPONSES BY SEX		MEAN NO. OF YEARS TEACHING	FREQUENCY OF RESPONSES BY GRADE							MEAN NO. OF SCIENCE CREDITS	MEAN FOR SCALES		
	M	F		K	1	2	3	4	5	6		1	2	3
SCIS n=7	1	6	7.14	0	1	1	2	2	1	0	9.86	4.57	3.86	4.43
ESS n=8	2	6	5.50	0	2	1	1	1	2	1	8.63	4.88	3.62	4.38
SAPA n=9	1	8	7.44	1	3	3	0	1	1	0	8.67	4.38	4.00	4.44
OTHER n = 1	0	1	40.00	1	0	0	0	0	0	0	6.00	--	--	--

1. On a scale of 1 to 5, rate your overall reaction to the 10 modules.

   1 2 3 4 5
   TERRIBLE EXCELLENT

2. On a scale of 1 to 5, rate your feelings as to how useful a competency-based program would be for you in the teaching of elementary science.

   1 2 3 4 5
   USELESS USEFUL

3. As an in-service teacher, rate your feelings on a scale of 1 to 5, the potential usefulness of a competency-based teacher education program for prospective teachers.

   1 2 3 4 5
   USELESS USEFUL

Table 25

Data for All Teachers

FREQUENCY BY SEX		SCIENCE CREDITS		GRADE LEVEL DISTRIBUTION							YEARS TEACHING		MEAN FOR SCALES		
M	F	MEAN	RANGE	K	1	2	3	4	5	6	MEAN	RANGE	1	2	3
4	21	8.88	6-15	2	6	5	3	4	4	1	8.40	1-40	4.24	3.52	4.24

Summary and Conclusions

Table 26 is a diagramatic representation of the procedures followed in the analysis of the three elementary science programs and the design of a competency-based elementary science teacher education program.

It was in the AAAS guideline IV, Scientific Knowledge, that there was a wide discrepancy as to the necessity of a given competency to teach elementary science. Although the content areas were drawn directly from the three projects, a majority of the selected panel of experts felt most of the content areas were unnecessary. As was cited in the review of the literature, the question of how much and what type of subject matter knowledge is appropriate for the prospective elementary teacher seems to be a never ending polemic among science educators.

The reaction to the modules by pre-service teachers was generally positive. Scale 3, which was directed toward the enjoyment level of participating in the modules, had a mean score of 4.51. Scale 5, directed toward the potential usefulness of the module in future teaching situations, had a mean score of 4.59. It would seem, from such evidence, that

Table 26

Summary of Procedures for Analysis and Design of
Competency-Based Teacher Education Program
In Elementary Science

SCIS

ESS

SAPA

INITIALLY SELECTED COMPETENCY OBJECTIVES

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE GUIDELINES

I	II	III	IV	V
SCIENTIFIC INQUIRY	ATTITUDES TOWARD SCIENCE	PROCESSES OF SCIENCE	SCIENTIFIC KNOWLEDGE	CONTINUOUS LEARNING
SIN	ATS	PRS	SCK	CTL

CODED AND ARRANGED INTO COMPETENCY HIERARCHIES

REVIEWED BY 16 MEMBER PANEL OF EXPERTS

FINAL COMPETENCY HIERARCHY

10 MODULES

EVALUATION BY PRE-SERVICE TEACHERS--EVALUATION BY IN-SERVICE TEACHERS the pre-service teachers had a favorable reaction to the ten modules.

It is interesting to note that a significant number of the participants had negative feelings toward science and viewed themselves as being somewhat incompetent to teach science in the elementary classroom. Scale 1, reflecting the students' interest level in science, had a mean score of 3.40 for all ten modules. Scale 2, indicating the feeling of confidence the pre-service teacher has for teaching science in the elementary school, had a mean score of 3.16. This data tends to support previously cited research that science is disliked by prospective teachers and they generally have a lack of self-confidence in their ability to teach science.

The in-service teachers tended to have positive feelings about the modules. Scale 1, which was an overall reaction to the modules, had a mean score of 4.24. SCIS and ESS teachers indicated that the modules would not be very useful to them in the teaching of elementary science. Mean scores of 3.86 and 3.62 respectively represent the SCIS and ESS teachers' responses to Scale 2. SAPA teachers with a mean of 4.00, however, generally viewed the competency modules as being useful to the teacher of elementary science. This would be expected given the nature of the program structure of SAPA which stresses learning hierarchies and competency objectives.

Scale 3, reflecting the in-service teachers' responses of the potential usefulness of the competency modules for prospective teachers, had a mean score of 4.25 for all teachers. Such evidence would seem to indicate that practicing teachers view the competency module approach as attractive strategy for teacher training.

The ten modules designed for this study in no way represents a panacea for the training of teachers in the area of elementary science. The problems related to the pre-service science education on the elementary level are multidimentional. What this study attempts to do is to bring into congruence the current philosophical values found in the new elementary science curricula and the pre-service preparation of teachers that will be using one of these curricula.

To this end, it can be stated:

1. The ten modules reflect an analysis of the competencies necessary to teach the new elementary science programs;
2. The competencies are organized within the stated AAAS guidelines;
3. The operational structure of the modules follow the content areas of the Natural History course recommended by the School of Education to elementary education majors.

The three statements represent an operationalization of the stated purposes of the dissertation indicated in Chapter I.

CHAPTER V

IMPLICATIONS FOR FURTHER STUDY

The effectiveness of any teacher education program ultimately depends on how the teachers that come through a given program effect student learning. Too little is known about the effectiveness of teacher preparation programs. The relationship between teacher behaviors and consequent learning by students has not been thoroughly investigated. Rosenshine and Furst indicate (1971):

> Perhaps the beginning of wisdom in the study and improvement of teaching behavior is the confession of our lack of knowledge that can be applied with confidence to a teacher education program. Educational researchers have <u>not</u> provided those who train teachers with a repertoire of teaching skills which indicate to a teacher that if he increases behavior X and/or decreases behavior Y, there will be a concomitant change in the cognitive or affective achievement of his students. It is time to stop touting structural panaceas and to begin developing the research which may produce the knowledge. [p. 40]

The major thrust in teacher education research must be toward evaluating the outcomes of instructional programs in terms of the teacher's performance in the classroom. Competency-based teacher education is the second in the three criteria approach suggested by Schalock (1970). The first criteria are those teacher education programs based on the acquisition of knowledge. Knowledge criteria programs are predicated on the assumption that knowledge of subject areas that relate to teaching is a sufficient predictor of the ability to perform the tasks required of a teacher. The second criteria is that of performance. In competency-based programs, specific teaching behaviors are identified and prospective teachers are expected to demonstrate these behaviors. Competency-based teacher education bridges the gap of knowing and doing. The third criteria, which has yet to be realized, is a product criteria program. The growth of pupils the teacher has taught becomes the evidence for the effectiveness of such a program.

Blosser and Howe (1969) after a comprehensive analysis of the research on teacher education related to the teaching of science, conclude "that elementary school science teaching is handicapped by deficiencies in both course content and teaching methodology. . ." [p. 58]. College students preparing to teach at the elementary school level cannot be trained as specialists in all of the subject-matter areas which they are called upon to teach in a self-contained classroom. It is for this precise reason that competency-based teacher education will prove to be an important innovation in the training of teachers.

What is now needed is research that will determine the behaviors necessary to teach the new elementary science programs. With the emphasis on self-directed learning in elementary science, science educators will have to focus on the identification of the behaviors that will facilitate the spirit of discovery.

Few research studies have been done to lead to the development of a theory of instruction relative to science teaching on the elementary level. Perhaps the teaching of science requires a unique set of behaviors that differ from the methods of other subjects.

Research needs to be done related to the ways in which elementary teachers handle the problem of individualization of science instruction and the manner in which they accommodate for individual differences.

Perhaps as Jacobson (1969) suggests, future elementary teachers should be trained in specific curriculum projects. Renner and Wilson (1969) performed an experiment to determine if there was a difference in teaching behaviors as a result of pre-service training in a specific science curriculum.

One group of undergraduates were trained in a methods course designed around the content and philosophy of the SCIS. A control group was exposed to a traditional methods course consisting of a broad range of topics and demonstrations. The investigators were interested in determining if there was a significant difference in the number of "essential science experiences encouraged by the SCIS-trained teachers and non-SCIS teachers," and if there was a significant difference in the type of questions asked by SCIS-trained teachers and non-SCIS teachers.

All of the students involved in the study were assigned to elementary classrooms not using the SCIS program. The teachers were observed for an entire year. Renner and Wilson found no significant difference in the types and frequency of science experiences. In the area of question-asking, there was a significant difference. SCIS teachers tended to ask higher order questions that required the students to demonstrate a skill, analyze data or synthesize observations. Non-SCIS-trained teachers tended to use recognition and recall questions.

A similar experiment was carried out by Perkes (1971) to determine if pre-service teachers trained in the philosophy of the ESS would talk less in class than non-ESS trained teachers. During the student teaching period, Perkes observed both groups of teachers using the Flanders Interaction Analysis. He found that those teachers trained in

ESS talked significantly less than the teachers not trained in ESS.

Research such as that of Perkes, and Renner and Wilson is essential in the design of teacher education programs. Teacher preparation should not be based on what an individual instructor "thinks" is important, but on process-product research. Even the Office of Education's Model programs do not describe how the particular behaviors were chosen. Intensive study is needed on what kind of teacher education programs, the process, will maximize student performance--cognitive or affective--the product.

The five guidelines suggested by the AAAS could provide a unique vehicle for further study in process-product research. The effectiveness of a teacher education program designed around these guidelines must be demonstrated within the environment of the classroom.

Guideline I -- Scientific Inquiry

Research is needed to determine if a given teacher education program encourages the opportunity to engage in open inquiry as a style of learning. As a result of inquiry training for prospective teachers, can it be demonstrated that teachers encourage inquiry on the part of children? The AAAS suggests five criteria that could be used to judge the effectiveness of an inquiry centered teacher education program:

1. The teacher acts as a guide to learning rather than simply as a dispenser of information.
2. The teacher values the asking of questions as well as the giving of answers.

3. The teacher understands that learning is cummulative and does not impose closure prematurely.
4. The teacher recognizes the importance of speculative thinking and does not insist that evidence be interpreted in conformity with cultural tradition.
5. The teacher recognizes that there are several alternative approaches to solving problems and provides opportunities for students to utilize means they find appropriate.

Guideline II -- Attitudes Toward Science

The area of attitude formation and changing belief systems has long been overlooked in teacher education programs. Few programs are being designed with attitude formation as an important component (Loree, 1971). There is some evidence (Aiken, 1969) on attitude changes after an exposure to a semester course or short experience, but no known research has been done on the long term effect of an attitude change.

There is a scarcity of evidence that would indicate realistic attitudes are being developed toward the possible solution of major problems such as population growth and environmental pollution. Research is needed to determine the effect of a pre-service teacher's changed belief system on their pupils over a long period of time.

Guideline III -- Processes of Science

The processes of science are skills that can be utilized in all phases of inquiry. Research is needed to provide data on whether or not the processes of science are encouraged in areas outside of science.

Dewey viewed the scientific method as an all encompassing methodology to acquire knowledge. If the processes of science remain isolated, little transfer of training will take place.

Evidence must be gained to determine if teachers trained in the processes of science can transfer these skills to other disciplines.

Guideline IV -- Scientific Knowledge

Research is needed to determine how the pre-service science program for elementary school teachers can be structured to provide as wide a range of experiences and instructional content in science as possible. Perhaps as Smith (1969) suggests, science educators will have to conceive of subject matter in a new perspective. He contends that the term subject-matter is composed of two facets. The first is the discipline of the subject. By discipline, Smith means "an area of inquiry containing a distinctive body of concepts and principles, with techniques for exploring the area and for correcting and explaining the body of knowledge." The second facet to subject matter is knowledge. Knowledge, according to Smith, "is used to designate information held to be true by a specific criterion such as the rules of empirical verification. . ." [p. 114]. A discipline is infinite; knowledge is finite.

There is a plethora of conflicting research (Blasser and Howe, 1969) on how much and of what type of science knowledge is considered adequate for an elementary teacher. Most of this research is predicated on the knowledge component of the subject science; little has been done to explore the discipline nature of science.

Guideline V -- Continuous Learning

As has been previously mentioned in Chapter II, there is almost no data on how a teacher education program can promote the capacity and disposition for continuous learning. Evidence is needed to determine if new information and experiences affect a pre-service teachers' attitudes, ideas, and teaching. Why do some teachers continue to read books and periodicals related to science and have a desire to continue their education in the field of science; while other teachers demonstrate little concern in keeping up with the recent developments?

Effective science teaching is not a step-by-step procedure. It is an interaction between children, teachers, materials, equipment, and facilities. The effective teacher nurtures, stimulates, and guides these interactions.

To bring about these behaviors, specific competencies have to be identified and operationalized into a relevant teacher education program. The field of science education cannot afford a "curriculum gap." The new elementary science programs require teachers that have the ability to facilitate an environment of inquiry, possess a unique set of attitudes toward science, can use the process of science in all disciplines, have a conceptual understanding of the scientific enterprise, and are predisposed to continuous learning. To these ends, this study represents a first step in the identification of the competencies necessary to bring about these goals.

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A P P E N D I C E S

APPENDIX A

The Commonwealth of Massachusetts
University of Massachusetts
Amherst 01002

HOOL OF EDUCATION

May, 1971

Dear

I am presently developing a competency-based program in elementary science education based upon the recent recommendations of the American Association for the Advancement of Science (AAAS). The AAAS recommends that the science experiences for the prospective teacher reflect the five following categories:

I. Scientific Inquiry
II. Attitudes Toward Science
III. Processes of Science
IV. Scientific Knowledge
V. Continuous Learning

The specific competencies subsumed by these categories were arrived at by an analysis of three widely used elementary school science projects. It is anticipated that a student exposed to such an offering will have the necessary competencies to teach the new science programs. The vehicle of instruction for the competency-based program will be a course in Natural History.

Before the program can become functional, I will need your professional judgment as to whether the competencies reflect the AAAS guidelines, and if they are necessary to teach the new elementary science programs. I am sending this survey to a number of science educators, science supervisors, and school administrators. The results will assist in the making of any changes or modifications.

Attached you will find an information cover sheet, the competency list, and a sheet for additional comments. If you wish further information on the program, please do not hesitate to write me.

Return the forms in the enclosed stamped and addressed envelope. Thanking you in advance, I remain

Yours truly,

Barry A. Kaufman

Barry A. Kaufman

The Commonwealth of Massachusetts
University of Massachusetts
Amherst 01002

CHOOL OF EDUCATION

May, 1971

Dear

A little over a month ago, I mailed to you a list of competencies I thought were necessary for a prospective elementary teacher to possess in the area of science. I realize how busy you must be at this time of the year. However, before the program for which these competencies will be utilized can become functional, it will be necessary to get your professional judgment as to their appropriateness.

The competency-based program in elementary science education is based upon the recent recommendations of the American Association for the Advancement of Science (AAAS). The AAAS recommends that the science experiences for the prospective teacher reflect the five following categories:

I. Scientific Inquiry
II. Attitudes Toward Science
III. Processes of Science
IV. Scientific Knowledge
V. Continuous Learning

The specific competencies subsumed by these categories were arrived at by an analysis of three widely used elementary school science projects. It is anticipated that a student exposed to such an offering will have the necessary competencies to teach the new science programs. The vehicle of instruction for the competency-based program will be a course in Natural History.

Attached you will find an information cover sheet, the competency list, and a sheet for additional comments. If you wish further information on the program, please do not hesitate to write me.

Return the forms in the enclosed stamped and addressed envelope. Thanking you in advance, I remain

Yours truly,

Barry A. Kaufman

Barry A. Kaufman

NAME____

INSTITUTION____

POSITION____

The following pages contain the specific competencies subsumed under the AAAS categories. Instructions precede each list.

If you wish to comment on a particular competency, please refer to it by the code number on the last page headed "Additional Comments." Feel free to make any recommendations on the competencies or omissions you view as necessary.

OPINION QUESTIONNAIRE ON COMPETENCIES

Please check (✓) YES or NO for the following two questions in reference to the stated competencies:

A - The competency reflects the stated guideline it is subsumed under.

B - The competency is necessary to teach the new elementary school science programs.

SCIENTIFIC INQUIRY (SIN)

A YES	A NO	B YES	B NO		
( )	( )	( )	( )	SIN-001.00	The ability to investigate.
( )	( )	( )	( )	SIN-001.01	To define a problem and suggest possible answers.
( )	( )	( )	( )	SIN-001.02	To devise and carry out experiments that might help to answer questions.
( )	( )	( )	( )	SIN-001.03	To control an experiment.
( )	( )	( )	( )	SIN-001.04	To formulate a system for recording data.
( )	( )	( )	( )	SIN-001.05	To process data so it becomes more meaningful.
( )	( )	( )	( )	SIN-001.06	To distinguish between observations that support an hypothesis and those that refute it.
( )	( )	( )	( )	SIN-001.07	To formulate conclusions.
( )	( )	( )	( )	SIN-001.08	To describe an investigation so it can be repeated by another person.
( )	( )	( )	( )	SIN-002.00	The ability to teach science as inquiry.
( )	( )	( )	( )	SIN-002.01	To teach science using the inquiry approach rather than the demonstration method.
( )	( )	( )	( )	SIN-002.02	To select inquiry techniques consistant with the child's learning abilty.
( )	( )	( )	( )	SIN-002.03	To emphasize inquiry learning rather than the memorization of facts.
( )	( )	( )	( )	SIN-002.04	To teach children inquiry skills.

ATTITUDES TOWARD SCIENCE (ATS)

A YES	A NO	B YES	B NO		
( )	( )	( )	( )	ATS-001.00	The ability to demonstrate an interest in and a positive attitude toward science.
( )	( )	( )	( )	ATS-001.01	To indicate how the local community has been affected by science and technology.
( )	( )	( )	( )	ATS-001.02	To participate in a local environmental protection group.
( )	( )	( )	( )	ATS-002.00	To encourage pupils to use the inquiry approach when asked a question.
( )	( )	( )	( )	ATS-003.00	To demonstrate an interest in science by reading books and articles not assigned.

OPINION QUESTIONNAIRE ON COMPETENCIES

Please check (√) YES or NO for the following questions in reference to the stated competencies:

A - The competency reflects the stated guideline it is subsumed under.

B - The competency is necessary to teach the new elementary school science programs

SCIENTIFIC KNOWLEDGE (SCK)

A YES	A NO	B YES	B NO	Code	Competency
( )	( )	( )	( )	SCK-001.00	The ability to describe the conceptual orientation and interaction of the earth, universe, biotic and abiotic world that can be used to explain natural phenomena.
( )	( )	( )	( )	SCK-001.01	To describe the earth-sun-moon relationships to explain seasonality and climatic phenomena.
( )	( )	( )	( )	SCK-001.02	To construct physical and mental models of the origin of the earth, solar system, and universe.
( )	( )	( )	( )	SCK-001.03	To describe the interactions involved in geological processes.
( )	( )	( )	( )	SCK-001.04	To reconstruct the geological history of a local area.
( )	( )	( )	( )	SCK-002.00	The ability to describe the processes of growth and reproduction in plants and animals.
( )	( )	( )	( )	SCK-002.01	To describe differences and similarities among several kinds of seeds.
( )	( )	( )	( )	SCK-002.02	To describe the major events in the germination of a seed.
( )	( )	( )	( )	SCK-002.03	To recognize the parts of a germinating seed.
( )	( )	( )	( )	SCK-002.04	To identify fruits as a source of seeds.
( )	( )	( )	( )	SCK-002.05	To state some general requirements for seed germination and plant growth.
( )	( )	( )	( )	SCK-002.06	To describe the differences between growth and development.
( )	( )	( )	( )	SCK-002.07.	To use the term "life cycle" to refer to the series of changes observed in an organism as it develops from egg to adult and produces eggs.
( )	( )	( )	( )	SCK-002.08	To use the term metamorphasis to refer to a change in body form.
( )	( )	( )	( )	SCK-002.09	To identify the four stages in the life cycle of a fruit fly.
( )	( )	( )	( )	SCK-002.10	To identify the major stages in the life cycle of a frog .
( )	( )	( )	( )	SCK-002.11	To describe the life cycle of a mealworm.
( )	( )	( )	( )	SCK 003.00	The ability to describe the interactions that exist among living organisms.
( )	( )	( )	( )	SCK-003.01	To use the term "habitat" to refer to a place where an organism lives.
( )	( )	( )	( )	SCK-003.02	To use the term "population" to refer to a group of plants or animals of one kind in a particular area.
( )	( )	( )	( )	SCK-003.03	To use the term "community" to refer to all populations live and interact within a particular area.
( )	( )	( )	( )	SCK-003.04	To describe food relationships among populations in a given area.
( )	( )	( )	( )	SCK-003.05	To recognize that all food chains begin with green plants.
( )	( )	( )	( )	SCK-003.06	To identify the food relationship among plants, plant eaters, and animal eaters as a food chain.
( )	( )	( )	( )	SCK-003.07	To use the term "food web" to refer to the feeding relationship among organisms.
( )	( )	( )	( )	SCK-003.08	To recognize that a food web is composed of food chains.
( )	( )	( )	( )	SCK-004.00	The ability to describe observations of living and non-living objects in terms of their physical, chemical, and biological composition, characteristics, .and structure.

OPINION QUESTIONNAIRE ON COMPETENCIES

Please check (✓) YES or NO for the following questions in reference to the stated competencies:

A - The competency reflects the stated guideline it is subsumed under.

B - The competency is necessary to teach the new elementary school science program.

A YES	A NO	B YES	B NO		
( )	( )	( )	( )	SCK-004.01	To describe the physical changes a geological system has undergone.
( )	( )	( )	( )	SCK-004.02	To identify the three main classes of rocks.
( )	( )	( )	( )	SCK-004.03	To identify the morphological characteristics of fruit flies, earthworms, frogs and crickets.
( )	( )	( )	( )	SCK-004.04	To describe the physical and biological processes
( )	( )	( )	( )	SCK-005.00	The ability to describe the evolutionary and genetic factors involved in plant and animal populations.
( )	( )	( )	( )	SCK-005.01	To establish genetic identity of a given seed to a given plant.
( )	( )	( )	( )	SCK-005.02	To describe the effects of variation on the evolution of a species.
( )	( )	( )	( )	SCK-005.03	To describe the relationship of form and function.
( )	( )	( )	( )	SCK-005.04	To describe the relationship of overpopulation and biotic potential .
( )	( )	( )	( )	SCK-006.00	The ability to describe the behavior patterns of an organism.
( )	( )	( )	( )	SCK-006.01	To describe the behavior patterns of mealworms, earthworms and crickets.

PROCESSES OF SCIENCE (PRS)

A YES	A NO	B YES	B NO		
( )	( )	( )	( )	PRS-001.00	The ability to make empirical observations
( )	( )	( )	( )	PRS-001.01	To observe the effect of changing environmental variables.
( )	( )	( )	( )	PRS-001.02	To observe the behavior of selected organisms.
( )	( )	( )	( )	PRS-001.03	To observe the anatomy of selected organisms.
( )	( )	( )	( )	PRS-001.04	To observe the effect of stimuli on the behavior of an organism.
( )	( )	( )	( )	PRS-001.05	To observe the life cycle of plants and animals.
( )	( )	( )	( )	PRS-001.06	To observe changes in the sky.
( )	( )	( )	( )	PRS-002.00	The ability to make reasonable inferences when presented with empirical data.
( )	( )	( )	( )	PRS-002.01	To identify statements that are inferences.
( )	( )	( )	( )	PRS-002.02	To describe observations which can be used to test an inference.
( )	( )	( )	( )	PRS-002.03	To distinguish between statements of observation and statements of inference.
( )	( )	( )	( )	PRS-002.04	To make inferences from the results of experiments.
( )	( )	( )	( )	PRS-002.05	To demonstrate that inferences may need to be altered on the basis of additional data.
( )	( )	( )	( )	PRS-003.00	The ability to make predictions based on observable data.
( )	( )	( )	( )	PRS-003.01	To construct tests of predictions.
( )	( )	( )	( )	PRS-003.02	To relate observations to predictions.
( )	( )	( )	( )	PRS-003.03	To construct a revision of a prediction on the basis of additional data.
( )	( )	( )	( )	PRS-003.04	To construct a relationship between two variables that can be used to make predictions.

OPINION QUESTIONNAIRE ON COMPETENCIES

Please check (✓) YES or NO for the following questions in reference to the stated competencies:

A - The competency reflects the stated guideline it is subsumed under.

B - The competency is necessary to teach the new elementary school science program.

A YES	A NO	B YES	B NO	Code	Competency
( )	( )	( )	( )	PRS-004.00	The ability to identify and control variables which may affect the results of an investigations.
( )	( )	( )	( )	PRS-004.01	To identify the factors in the environment that may affect the growth and reproduction of plants and animals.
( )	( )	( )	( )	PRS-004.02	To investigate the affects of varying environmental factors on the growth of organisms.
( )	( )	( )	( )	PRS-004.03	To recognize that changes in the environment caused by one organism can affect another.
( )	( )	( )	( )	PRS-005.00	The ability to measure variables.
( )	( )	( )	( )	PRS-005.01	To measure length in standard and arbitary units.
( )	( )	( )	( )	PRS-005.02	To measure mass in standard and arbitary units.
( )	( )	( )	( )	PRS-005.03	To measure volume in standard and arbitary units.
( )	( )	( )	( )	PRS-006.00	The ability to construct and use classification scheme.
( )	( )	( )	( )	PRS-006.01	To identify and name the properties or characteristics on which to base a single stage classification system.
( )	( )	( )	( )	PRS-006.03	To construct and demonstrate the use of a classification scheme for a collection of materials that uniquely identifies each object in the collection.
( )	( )	( )	( )	PRS-007.00	The ability to communicate the procedures and results of an investigation.
( )	( )	( )	( )	PRS-007.01	To describe a sequence of events in an inquiry investigation.
( )	( )	( )	( )	PRS-007.02	To construct a graph based on observational data.

CONTINUOUS LEARNING (CTL)

A YES	A NO	B YES	B NO	Code	Competency
( )	( )	( )	( )	CTL-001.00	The ability to demonstrate the capacity and disposition for continuous learning.
( )	( )	( )	( )	CTL-001.01	To identify and describe conflicting scientific issues.
( )	( )	( )	( )	CTL-001.02	To obtain information on scientific issues related to education.
( )	( )	( )	( )	CTL-001.03	To identify the interrelationship of science to other areas of knowledge.
( )	( )	( )	( )	CTL-001.04	To identify a weakness in the students own scientific background and provide a way of correcting it.

APPENDIX B

WHAT IS COMPETENCY-BASED TEACHER EDUCATION

Competency-based teacher education is a new idea in the preparation of future teachers. It is based on the assumption that to be an affective teacher one must acquire the necessary knowledge, skills, and attitudes to promote learning. Instead of defining a qualified teacher on the number of courses and credits he has accumulated in college, a specific number of competencies are identified which the prospective teacher is expected to acquire. Competency-based teacher education bridges the gap of what a pre-service teacher learns in college and the competencies needed to be an effective teacher.

The philosophy of modern elementary science curricula emphasizes the child's individual learning style and the processes involved in scientific discovery. The traditional view of science education saw the need to transmit to the child the specific facts or products of science. It is for this reason that so many people dislike science. Science is not memorizing formulas, laws, and facts. The true beauty of science is found in the magic of discovery. Science becomes a verb - a process.

The question for teacher education in elementary science is what competencies are necessary to promote the true inquiry nature of science in the classroom? To often the prospective elementary teacher's own education in science has been one of rote memorization and a dry recall of facts. Competency-based teacher education attempts to overcome these barriers by identifying the necessary skills, knowledge, and attitudes to be an affective elementary science teacher who will promote inquiry learning in the classroom.

Proceeding each module is a series of competencies that you will hopefully acquire as a result of completing the experience. There is also a list of Performance Objectives that will indicate the method by which one can achieve the competencies.

The key to competency-based teacher education is the individualization of instruction. There is NO right or wrong answer to any of the activities. The main concern is the attainment of the competencies which then can be used to promote similar conditions in the elementary classroom. There is no time limit, therefore work at your own pace. Remember, no two people learn the same way.

At the end of each activity is a evaluation sheet. Please be as honest as possible. To improve teacher education we need input from you, the future teacher.

GENERAL DIRECTIONS

1. Read through the list of competencies - pay no attention to the code numbers.
2. Read the Performance Objectives - they will tell you what to do.
3. Follow the specific directions after the Performance Objectives.
4. If materials are missing let me know.
5. Fill out evaluation sheet.

Thank you,

Barry Kaufman

AQUARIA

Competencies

Scientific Inquiry (SIN):

SIN-001.00 THE ABILITY TO INVESTIGATE.
SIN-002.00 THE ABILITY TO TEACH SCIENCE AS INQUIRY.

Processes of Science (PRS):

PRS-001.00 THE ABILITY TO MAKE EMPIRICAL OBSERVATIONS.
.01 To observe the behavior of selected organisms.
PRS-004.00 THE ABILITY TO IDENTIFY AND CONTROL VARIABLES WHICH MAY EFFECT THE RESULTS OF AN INVESTIGATION.
.01 To identify the factors in the environment that may effect the growth and reproduction of plants and animals.
.03 To recognize that changes in the environment caused by on organism can effect another.
PRS-007.00 THE ABILITY TO COMMUNICATE THE PROCEDURES AND RESULTS OF AN INVESTIGATION.

Scientific Knowledge (SCK):

SCK-003.00 THE ABILITY TO DESCRIBE THE INTERACTIONS THAT EXIST AMONG LIVING ORGANISMS.

Performance Objectives

Scientific Inquiry:

1. The student will maintain a balanced aquarium consisting of guppies, snails, elodea for a period of seven days.

2. The student will suggest possible investigations that can be carried on by elementary age youngsters using an aquarium.

Processes of Science:

1. The student will observe the aquarium for a period of seven days.

2. The student will maintain a log of the observations.

3. The student will identify any possible environmental factors that would cause changes in the aquarium.

4. The student will identify environmental changes in the aquarium that could be caused by organisms present in the aquarium.

Scientific Knowledge:

1. In the students own words, he will describe the interactions that exist among the living organisms in the aquarium.

AQUARIA

Almost all of the current elementary science curricula provide for a unit on the maintenance of an aquarium. These units are intended to provide for the student a means of investigating the interactions that exist among living organisms. In the module that follows, you will maintain an aquarium and investigate some of the interactions that exist.

Materials:

Water, aged at least 24 hours
guppies, at least one female and three males
one gallon aquarium tank
some sprigs of elodea or other aquatic plant
sand
snails
fish food

Procedure:

1. Set up the aquarium according to the enclosed directions.
2. Observe the aquarium for a period of at least seven days.
3. Follow the Performance Objectives to complete the laboratory sheet.

CLASSIFICATION

Competencies

Processes of Science (PRS):

PRS-001.00 THE ABILITY TO MAKE EMPIRICAL OBSERVATIONS
PRS-006.00 THE ABILITY TO CONSTRUCT AND USE CLASSIFICATION SCHEMES
.01 To identify and name the properties or characteristics on which to base a single stage classification system.
.02 To construct and demonstrate the use of a classification scheme for a collection of materials that uniquely identifies each object in the collection.

Performance Objectives

Processes of Science:

1. The student will key out the name of a creature.
2. The student will construct a key for an imaginary creature.
3. The student will key out a single twig from a group of similar twigs.

CLASSIFICATION

An identification or classification key is a simple tool that enables one to quickly and easily find the name of an organism. Most keys are so constructed that there are always two alternatives in the sequence. This is called a DICOTOMOUS key. For example, all organisms can be divided into two major categories:

1A. Plants
1B. Animals

Each of these categories can then be subdivided into two alternatives. For example:

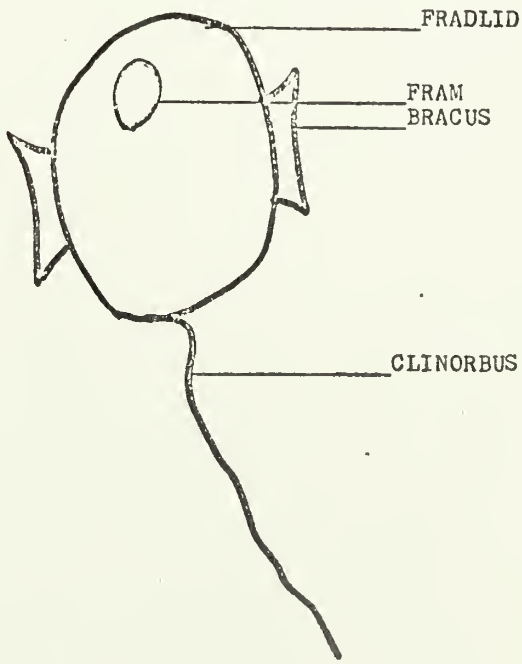
1A. Plants -- see 2
1B. Animals -- see 3

2A. Plants with flat leaves
2B. Plants with needle like leaves

3A. Animals with backbones
3B. Animals without backbones

Each of these subcategories can then be divided again so that there are two alternatives for each category. This process is then continued until such time as you cannot divide the categories any further and then the organisms name appears.

Before you can key out a specific organism, you must be familiar with the anatomical terminology on which the classification scheme is based. Try to key out this imaginary creature. On the next page is a key.



KEY

1A. Organisms with clinorbus......................2
1B. Organisms without clinorbus...................6

2A. Organisms with one or more frams..............3
2B. Organisms without frams.......................Simplex otatus

3A. Organisms with one fram.......................4
3B. Organisms with more than one fram.............7

4A. Organisms with one or more bracus.............5
4B. Organisms without bracus......................Spotux rightus

5A. Fram toward the front.........................Spotux upus
5B. Fram in the center............................8

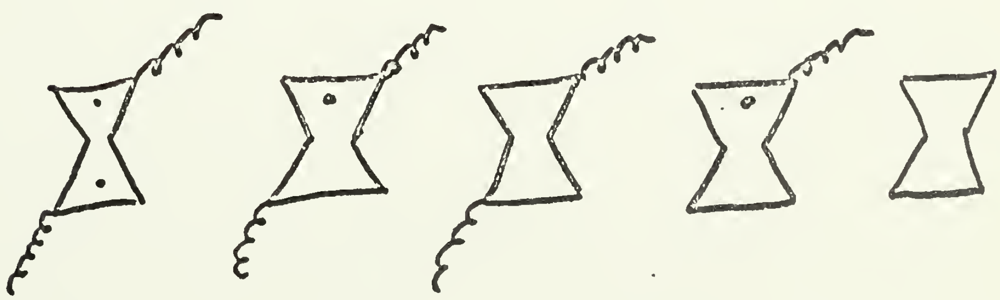
6A. Organisms with fram...........................Spotux framus
6B. Organisms without fram........................Spotux terminus

7A. Round fralid..................................Spotux cyclopis
7B. Oval fralid...................................Spotux ovalus

8A. One fram......................................Spotux singularus
8B. Two frams.....................................Spotux oppostitus

What was the name of the imaginary creature?________________________

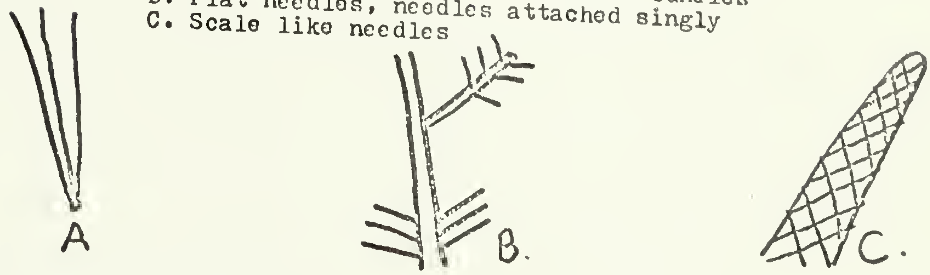
Here are a group of imaginary creatures. Make up names for the parts of their bodies and design a dicotomous key.



Using the following key, try to key out the name of this twig.

There are three common leaf patterns found among the evergreens.

A. Needle-like leaves, attached in bundles
B. Flat needles, needles attached singly
C. Scale like needles



1A. Needles in bundles................................2
1B. Needles not in bundles............................4

2A. Needles in fives..................................White pine
2B. Needles in twos...................................3

3A. Needles long, 3-8 inches in length................Red pine
3B. Needles short, 1-3 inches in length...............Scotch pine

4A. Needles flat and singly attached..................5
4B. Needles scale-like................................7

5A. Flat needles arranged in single horizontal plane..hemlock
5B. Flat needles arranged aroung the twig.............6

6A. Needles green, drooping dark green branches.......Norway spruce
6B. Needles gray-green, gray-blue, horizontal branches...Blue spruce

7A. Needles are smooth, rounded, flattened scales.....White cedar
7B. Two types of needles-short, sharp needles and scaly; flattened needles on a squarish twig...Red cedar

DAYTIME ASTRONOMY

Competencies

Scientific Inquiry (SIN):

SIN-001.00 THE ABILITY TO INVESTIGATE
- .02 To devise and carry out experiments that might help to answer questions.
- .05 To process data so it becomes more meaningful.
- .06 To distinguish between observations that support an hypothesis and those that refute it.
- .07 To formulate conclusions.

Processes of Science (PRS):

PRS-001.00 THE ABILITY TO MAKE EMPIRICAL OBSERVATIONS.
PRS-002.00 THE ABILITY TO MAKE REASONABLE INFERENCES WHEN PRESENTED WITH EMPIRICAL DATA.
- .04 To make inferences from the results of experiments.

PRS-005.00 THE ABILITY TO MEASURE VARIABLES
- .01 To measure length in standard and arbitary units.

Scientific Knowledge (SCK):

SCK-001.00 THE ABILITY TO DESCRIBE THE CONCEPTUAL ORIENTATION AND INTERACTION OF THE EARTH, BIOTIC AND ABIOTIC WORLD THAT CAN BE USED TO EXPLAIN NATURAL PHENOMENA.

Perfomance Objectives

Scientific Inquiry:

1. The student will carry on an independent investigation of the changing length of shadows on a daily basis and over an hourly time period.

2. The student will make predictions before gathering data on the change in shadow length, direction of the sun's movement, and the direction of the shadow's movement.

3. The student will complete a laboratory data sheet.

4. The student will accept, reject, or modify the predictions based on the data collected.

Processes of Science:

1. The student will observe the changing length of shadow over a four hour period and a week period.

2. Using the empirical data, the student will construct a hypothesis concerning the rotation and revolution of the earth.

3. The student will measure the length of a shadow cast by a shadow stick and the direction of the shadow and sun.

Scientific Knowledge:

1. The student will explain the physical basis of day and night.

DAYTIME ASTRONOMY

Laboratory Sheet

Introduction:

The sun seems to be in constant motion. We see it rise in the morning and set in the evening. This apparent motion across the Earth causes shadows to shrink and elongate.

The apparent movement of the sun is really caused by two motions of the Earth; rotation and revolution. These are difficult concepts for children to grasp. It is anticipated that the following module will provide the prospective teacher with a vehicle to present such a concept in concrete terms.

The Earth's Rotation:

Materials: a shadow stick
a compass
a ruler

Procedure:

In this exercise, you will measure shadow lengths at various times during the day to get a feeling for the Earth's motion called rotation.

1. Force the shadow stick several inches into the earth and as straight as possible.

2. Measure the length of the stick that is above the ground.

3. Before proceeding with any other measurements, try to predict your results by answering the following questions.

   A. What will happen to the shadow lengths as the day proceeds? ________
   ____
   ____
   ____

   B. In what direction will the shadow move? ____________________
   ____

   C. When will the shadow be the shortest? ____________________
   ____

4. Once every four hours, measure the compass direction of the sun (if you do not know how to use a compass, refer to the direction sheet in the folder called Using a Compass), measure the length of the shadow, and the compass direction of the shadow.

5. Fill in your results on the data sheet.

The Earth's Revolution:

Materials:
- a shadow stick
- a compass
- a ruler

Procedure:

In this experiment you will measure shadow lengths at the same time over a period of five days to get a feeling for the second motion of the earth called revolution.

1. Place the shadow stick as straight as possible in the ground.
2. Measure the length of the stick that is above the ground. Make sure each time you make measurements the same length of stick is above the ground.
3. Before proceeding with any other measurements, try to predict your results by answering the following questions.
   - A. Do shadows marked at the same time of the day over a period of five days point in the same direction?________________
   - B. Will a 2:00 P.M. shadow on day one fall on precisely the same place on day five?________
   - C. What will happen to the shadow length as we approach December 25th?________________
4. Choose a time during the day that you will be doing your measuring. Keep the same time for the five day period. Note the time on the data sheet.
5. For five consecutive days, at the same time, measure the compass direction of the sun, the shadow length, and the the shadows direction.
6. Fill in your results on the data sheet.

DATA SHEET

	HOUR ONE	HOUR TWO	HOUR THREE	HOUR FOUR
LENGTH OF STICK				
DIRECTION OF SUN				
LENGTH OF SHADOW				
DIRECTION OF SHADOW				

Observations:

A. When was the shadow length the shortest?____________________

B. When was the shadow length the longest?____________________

C. In what direction did the sun move?____________________

D. In what direction did the shadow move?____________________

Conclusions:

A. How do your predictions compare to what the data indicates?

____

____

____

____

B. If the sun seems to rise in the East and set in the West. in what direction is the Earth moving?____________________

C. Why do shadow lengths change?____________________

____

D. Is noon on the clock always midday?____________________

Explain.____

____

E. If the sun rises at 7:00 A.M. and sets at 5:30 P.M., when will midday be?____________________

DATA SHEET

	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	
TIME OF DAY						
SUN' DIRECTION						
SHADOW LENGTH						
SHADOW DIRECTION						

Obsevations:

A. How do your predictions compare to what the data indicates?

____

____

____

____

B. What happened to the shadow length over a period of five days?

____

C. In what direction did the shadow move?____________________

____

D. In what direction did the sun Move?____________________

Conclusions:

A. In what direction is the earth moving around the sun?____________________

____

B. In your words describe how the relationship of the Earth and the sun bring about day and night?

GROWING SEEDS

Competencies

Scientific Inquiry (SIN):

SIN-001.00 THE ABILITY TO INVESTIGATE
- .01 To define a problem and suggest possible answers.
- .02 To devise and carry out experiments that might help to answer questions.
- .03 To control an experiment.
- .04 To formulate a system for recording data.
- .06 To distinguish between observations that support an hypothesis and those that refute it.
- .07 To formulate conclusions.

Processes of Science(PRS):

PRS-001.00 THE ABILITY TO MAKE EMPIRICAL OBSERVATIONS.

PRS-004.00 THE ABILITY TO IDENTIFY AND CONTROL VARIABLES WHICH MAY AFFECT THE RESULTS OF AN INVESTIGATION.
- .01 To identify the factors in the environment that may affect the growth and reproduction of plants and animals.

PRS-007.00 THE ABILITY TO COMMUNICATE THE PROCEDURES AND RESULTS OF AN INVESTIGATION.
- .01. To describe a sequence of events in an inquiry investigation.
- .02 To construct a graph based on observational data.

Scientific Knowledge (SCK)

SCK-002.00 THE ABILITY TO DESCRIBE THE PROCESSES OF GROWTH AND REPRODUCTION IN PLANTS AND ANIMALS.
- .03 To state some general requirements for seed germination and plant growth.

Performance Objectives

Scientific Inquiry:

1. The student will investigate the effect of two contrasting environmental variables on the growth of a seed.
2. The student will suggest possible outcomes of the investigation.
3. The student will formulate conclusions as to the effect of the environmental variation on the growth of the plants.

Processes of Science:

1. The student will maintain an observational log on the investigation.
2. The student will write a detailed report on the procedures and results of the investigation.

3. The student will construct a graph to indicate the growth of the plant on a daily basis.

Scientific Knowledge:

1. The student will state some general conditions for plant growth.

GROWING SEEDS

Almost all of the current elementary science curricula provide for a unit on the growing of seeds. These units are intended to provide for the student a means of investigating and isolating different environmental conditions that will allow for the optimal growth of plants.

Some of these environmental variables include:

a. planting seeds in soil and in sand to compare the growth rates

b. raising plants in the light and in the dark

c. varying the depth of the seed

Materials: Seeds
Planting container
Soil and sand
Ruler

Procedure:

1. In this investigation, you are to choose one environmental variable, either from the above list or one of your own.

2. You are to design your own experiment to see the effects of the variable on the growth of the plant.

3. Follow the Performance Objectives to complete the laboratory sheet.

INQUIRY INVESTIGATION FOR CHILDREN

Competencies

Scientific Inquiry (SIN):

SIN-002.00 THE ABILITY TO SCIENCE AS INQUIRY.

.01 To teach science using the inquiry approach rather than the demonstration method.

.02 To select inquiry techniques consistant with the child's learning ability.

.03 To emphasize inquiry techniques rather than the memorization of facts.

Performance Objectives

Scientific Inquiry:

1. The student will design an inquiry investigation to be used with a small group of elementary age youngsters.

2. The student will try the investigation with a small group of elementary age youngsters.

INQUIRY INVESTIGATION FOR CHILDREN

Too often, methods classes do not give pre-service teachers the opportunity to try out ideas. In this module, you will design an inquiry investigation for a small group of youngsters and then try it out. If you need equipment, let me know.

Procedure:

1. Design an inquiry investigation.

2. Get yourself some kids to try it out.

LETTER TO THE EDITOR

Competencies

Continuous Learning (CLT):

CLT-001.03 THE ABILITY TO DEMONSTRATE THE CAPACITY AND DISPOSITION FOR CONTINUOUS LEARNING.
.03 To identify the interrelationship of science to other areas of knowledge.

Attitudes Toward Science (ATS):

ATS-001.00 THE ABILITY TO DEMONSTRATE AN INTEREST IN AND A POSITIVE ATTITUDE TOWARD SCIENCE.

Performance Objectives

Continuous Learning:

1. The student will identify an area of science that in some way is directly affecting the needs of the community.

Attitudes Toward Science:

1. The student will write and send to any periodical a letter to the editor commenting on the identified area of concern.

LETTER TO THE EDITOR

So often science becomes a self-contained discipline with little connection made between the needs and problems of a community. Few teachers attempt to demonstrate how science is related to the community in which we live. In this module, you will identify one area of science that is some way related to the needs of the community, i.e., the Amherst-Northampton vacinity.

Procedures:

1. Identify one area of science that directly concerns the community.

2. Draft a letter to the editor of any periodical or newspaper, local or University based. Explain how you feel about your concerns.

ONE SQUARE FOOT FIELD TRIP

Competencies

Processes of Science (PRS):

PRS-001.00 THE ABILITY TO MAKE EMPIRICAL OBSERVATIONS

Scientific Knowledge (SCK):

SCK-003.00 THE ABILITY TO DESCRIBE THE INTERACTIONS THAT EXIST AMONG LIVING ORGANISMS.
- .01 To use the term "habitat" to refer to a place where an organism lives.
- .02 To use the term "population " to refer to a group of plants or animals of one kind in a particular area.
- .03 To use the term "community" to refer to all populations that live and interact within a particular area.

Performance Objectives

Processes of Science:

1. The student will observe a one square foot of land for a period of time.

Scientific Knowledge:

1. The student will describe the interactions that exist among the living organisms and non-living objects on the square foot of land.
2. The student will identify the the habitat of the square foot of land.
3. The student will identify the population of plants and animals on the square foot of land.
4. The student will describe the community that exists on the square foot of land.

ONE SQUARE FOOT FIELD TRIP

There are many reasons elementary teachers do not go on field trips. Some of these include not enough money for buses, no place to take the children, and teachers who are afraid they do not hav the necessary skills.

This module demonstrates that you do not need a very large area for a field trip, as a matter of fact, one square foot is all that is needed. This does not even have to be a square foot of earth (dirt); it could be a square foot of concrete.

Procedures:

1. Locate a one square foot of land. Any piece will do.
2. Observe it for a period of time of not less than ten minutes.
3. Write down what you see. Observe longer if necessary.

Observations:

1. What kind of interactions, if any, did you find on your square foot of land?
2. Describe the habitat of the one square foot.
3. Describe the plant and animal populations on the one square foot.
4. What kind of community exists on the square foot of land?
5. If you are inspired to write a poem or to do some art about your square foot of land, please feel free to do so.

A QUESTION ABOUT THE WEATHER

Competencies

Continuous Learning (CLT):

CLT-001.00 THE ABILITY TO DEMONSTRATE THE CAPACITY AND DISPOSITION FOR CONTINUOUS LEARNING.
.04 To identify a weakness in the students own scientific background and provide a way of correcting it.

Performance Objectives

Continuous Learning:

1. The student will state a question in the area of meteorology that represents a weakness in the students own background.

2. The student will provide a mechanism for answering the question.

A QUESTION ABOUT THE WEATHER

One of the earliest forms of environmental changes recognized by a child is the weather. Weather changes are obvious variables that affect the daily lives of children. It is for this reason children ask so many questions about the weather. Questions such as: Why is the sky blue or what makes it rain? In this module, you will identify a question you would like to know the answer to. Once you have identified the question, you will attempt to find out the answer.

Procedure:

1. Think of a question that has bothered you about any phase of weather and climate. Think back; were all of your questions answered when you were a child?

2. Now find out the answer.

What is your question? ______________________________

____

____

How did you answer it? ______________________________

____

____

What was the answer? ______________________________

____

____

STORY IN THE ROCKS

Competencies

Processes of Science (PRS):

PRS-001.00 THE ABILITY TO MAKE EMPIRICAL OBSERVATIONS.
PRS-001.00 THE ABILITY TO MAKE REASONABLE INFERENCES WHEN PRESENTED WITH EMPIRICAL DATA.

Performance Objectives

Processes of Science:

1. The student will make inferences about the possible geological history of an area based on the observation of some fossils.

STORY IN THE ROCKS

These rocks were found in a mountainous region. What kind of inferences can you make regarding the geological history of the area?

Use your imagination to create a story. Be as creative as possible. Remember, today's fiction could be tomorrow's truth.

VARIATION

Competencies

Scientific Inquiry:(SIN):

SIN-001.00 THE ABILITY TO INVESTIGATE
.04 To formulate a system for recording data.
.05 To process data so it becomes more meaningful.

Processes of Science (PRS):

PRS-005.00 THE ABILITY TO MEASURE VARIABLES
.01 To meaoure length in standard and arbitary units.
PRS-007.00 THE ABILITY TO COMMUNICATE THE PROCEDURES AND RESULTS OF AN INVESTIGATION
.02 To construct a graph based on observational data.

Scientific Knowledge(SCK):

SCK-005.00 THE ABILITY TO DESCRIBE THE EVOLUTIONARY AND GENETIC FACTORS INVOLVED IN PLANT AND ANIMAL POPULATIONS.

Performance Objectives

Scientific Inquiry:

1. The student will carry on an independent investigation on the genetic variation of a lima bean.

2. The student will formulate a system for recording data in order that the data can be represented graphically.

Processes of Science:

1. The student will measure in millimeters the length of 100 lima beans.

2. The student will construct a graph to communicate the results of the investigation.

Scientific Knowledge:

1. The student will describe the significance of the graph to the process of evolution.

2. The student will describe the relationship of genetic variation to the process of evolution.

VARIATION

Materials:

100 lima beans
a millimeter ruler

Procedure:

1. Measure the 100 lima beans with the millimeter ruler.
2. Formulate a system for recording your results.
3. Draw a graph that represents your results.
4. What is significant about the shape of the graph?
5. In your own words, try to draw some relationship be- the graph and the process of evolution.
6. What would happen if every lima bean was exactly alike?
7. Why is variation so important to evolution?

APPENDIX C

EVALUATION FORM

Directions: Please fill out the following evaluation form soon after you complete the module. Try to answer all items. Place the completed forms in the folder or directly to me. Thank you ever so much. Barry Kaufman

1. Name of the module being evaluated________________________________

2. Class(circle one): Freshman Sophomore Junior Senior Graduate

3. Credits to date in college level science(not including methods course)____________

4. On a scale of 1 to 5, rate your present interest in science(circle one).

   1 ____ 2 ____ 3 ____ 4 ____ 5
   DISLIKE LIKE

5. On a scale of 1 to 5, rate your feeling of competency to teach science to elementary school youngsters(circle one).

   1 ____ 2 ____ 3 ____ 4 ____ 5
   INCOMPETENT COMPETENT

6. On a scale of 1 to 5, rate your feelings about how much you enjoyed participating in the module(circle one).

   1 ____ 2 ____ 3 ____ 4 ____ 5
   DID NOT ENJOY FULLY ENJOYED

7. How would you change or modify the module for pre-service and in-service teachers.

8. On a scale of 1 to 5, rate your level of achievement of the stated competencies.

   1 ____ 2 ____ 3 ____ 4 ____ 5
   NONE ACHIEVED FULLY ACHIEVED

9. On a scale of 1 to 5, rate the potential usefulness of the module in your career as an elementary school teacher.

   1 ____ 2 ____ 3 ____ 4 ____ 5
   USELESS USEFUL

10. How would you apply the module to a teaching experience with young children?

A P P E N D I X D

The Commonwealth of Massachusetts
University of Massachusetts
Amherst 01002

SCHOOL OF EDUCATION

October, 1971

Dear

I am presently involved in the designing of a competency-based teacher education program in the area of elementary science education. Competency-based programs are intended to bridge the gap between what is learned in college and the competencies necessary to be an effective classroom teacher.

The operational unit of a competency-based program is known as a module. In each module, specific competencies are identified which the teacher is expected to acquire. The competencies for the enclosed program have been arrived at by an analysis of three widely used curriculum projects in elementary science. The attainment of these competencies are operationalized in the form of performance objectives the prospective teacher is expected to complete.

I am now field testing ten of these modules with several undergraduate education majors at the University of Massachusetts. To make the program as effective as possible, I would like to get reactions to the modules from classroom teachers presently using one of the National Science Foundation sponsored elementary science projects.

I would appreciate it if you would distribute the enclosed material to a random selection of your teachers. Try to include various grade levels, different periods of length of service, and sex. Each packet contains an informational cover letter, an evaluation form, the ten modules, and a return envelope for the completed evaluation.

I would like the teachers to look through the modules and then fill out the evaluation form. If you have any questions, please write to me and I will gladly reply.

Yours truly,

Barry A. Kaufman

Barry A. Kaufman

The Commonwealth of Massachusetts
University of Massachusetts
Amherst 01002

SCHOOL OF EDUCATION

October, 1971

Dear Teacher:

I am presently involved in the designing of a competency-based teacher education program in the area of elementary science education. Competency-based programs are intended to bridge the gap between what is learned in college and the competencies necessary to be an effective classroom teacher.

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I am now field testing ten of these modules with several undergraduate education majors at the University of Massachusetts. To make the program as effective as possible, I would like to get reactions to the modules from classroom teachers presently using one of the National Science Foundation sponsored elementary science projects.

I would appreciate if you looked through the attached modules and reacted to them. To provide feedback from you, I have enclosed an evaluation form and a stamped return envelope. A good judge of the possible effectiveness of a pre-service teacher education program are practicing teachers.

I know how busy you must be, but a few minutes of your valuable time could bring about some important changes in pre-service teacher education in the area of science.

Yours truly,

Barry A. Kaufman

Barry A. Kaufman

EVALUATION FORM

Directions: Please try to answer all items. If you wish to respond in detail to a given item, please feel free to do so. Return the evaluation form in the enclosed stamped self-addressed envelope. Thank you ever so much.

1. Sex(circle one): Male Female

2. Presently teaching grade level(circle one): K 1 2 3 4 5 6

3. Number of years teaching_____________

4. Which elementary school science program are you using? Science Curriculum Improvement Study (SCIS) Elementary Science Study (ESS) Science: A Process Approach (SAPA)

   Other______________________________
   Specify

5. Number of science credits in college level science(undergraduate and graduate)____________

6. On a scale of 1 to 5, rate your overall reaction to the 10 modules.

   1 ____ 2 ____ 3 ____ 4 ____ 5
   TERRIBLE EXCELLENT

7. On a scale of 1 to 5, rate your feelings as to how helpful a competency-based program would be for you in the teaching of elementary science.

   1 ____ 2 ____ 3 ____ 4 ____ 5
   USELESS USEFULL

8. What changes or modifications would you make in the modules?

9. As an in-service teacher, rate your feelings on a scale of 1 to 5, the potential usefulness of a competency-based teacher education program for prospective teachers.

   1 ____ 2 ____ 3 ____ 4 ____ 5
   USELESS USEFUL

10. How can competency-based education be applied to elementary school children in the area of science?